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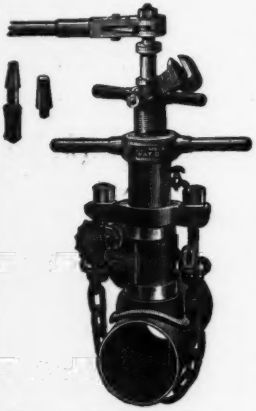

MUELLER COLUMBIA TAPPING MACHINE

Wrought and Cast Iron Pipe and Fittings

Water, Steam and Gas Fitters' Tools and Supplies

Buffalo and Jarecki Service Boxes

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ORGANIZED 1882.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

METROPOLITAN WATER WORKS PUMPING MACHINERY.

BY WILL J. SANDO, UNTIL RECENTLY SUPERINTENDENT OF PUMPING STATIONS, METROPOLITAN WATER WORKS, BOSTON, MASS.

[*Read January 9, 1901.*]

On the first day of January, 1898, the Metropolitan Water Board began supplying the Metropolitan District with water. The pumping stations controlled and operated by the board at that time, two in number, were located at Chestnut Hill Reservoir and Melrose. The pumping equipment consisted of machinery having an aggregate daily capacity of 36 000 000 United States gallons, representing about 1 050 horse power.

To-day the board controls and operates five pumping stations, located as follows: two at Chestnut Hill Reservoir, one for the high service and one for the low service; one at Spot Pond (this station superseded the one at Melrose); one at Arlington; and one at West Roxbury (the latter leased from the city of Boston). There is also a pumping station at Clinton, Mass., used for pumping sewage, which will not be considered at this time. The aggregate daily capacity is 203 380 000 gallons in twenty-four hours, representing about 3 775 horse power.

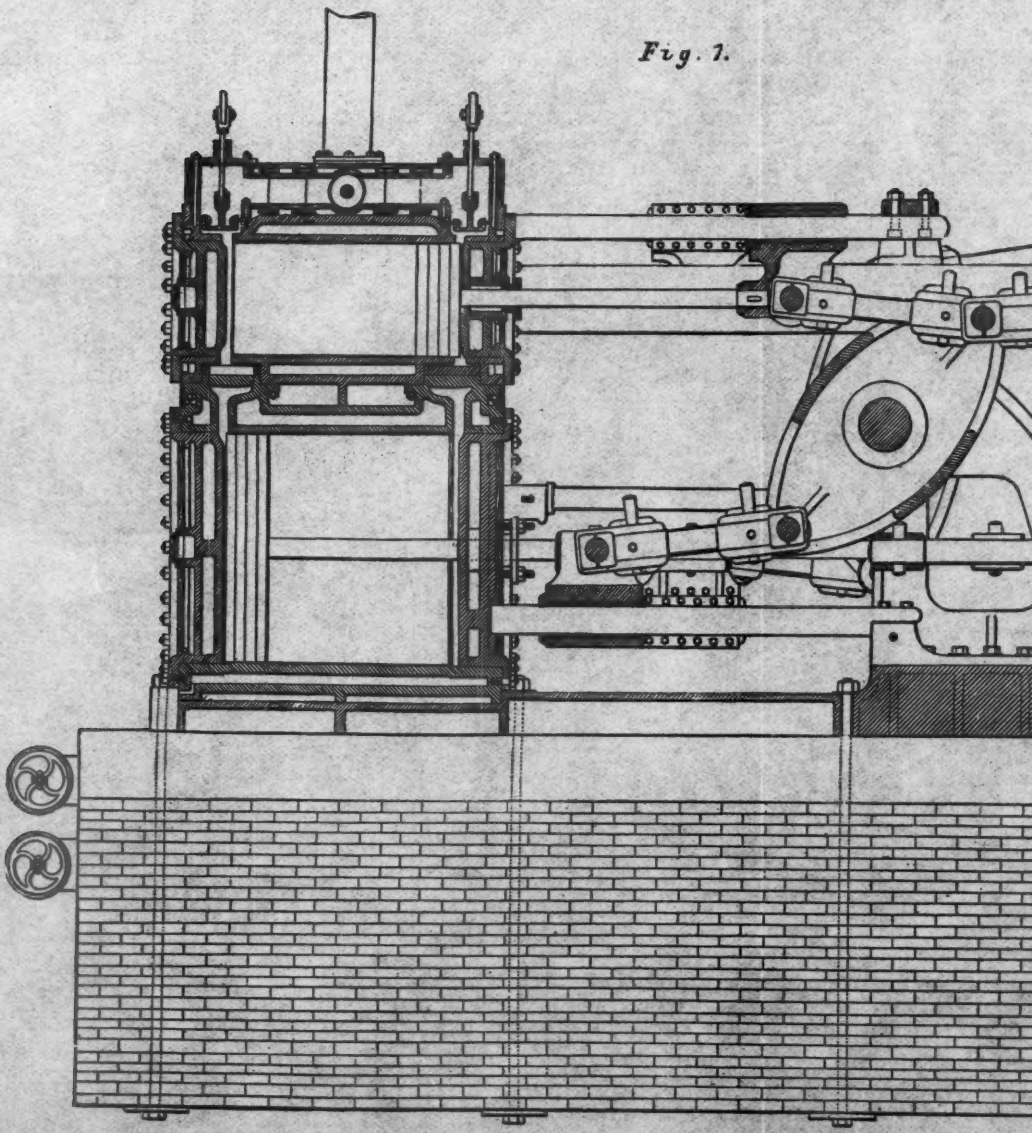
The principal dimensions of the engines and boilers in the several pumping stations are given in Tables Nos. 1 and 2.

The cost of pumping one million gallons of water one foot high during the year 1899 ranged from 2.3 cents to 30.9 cents.

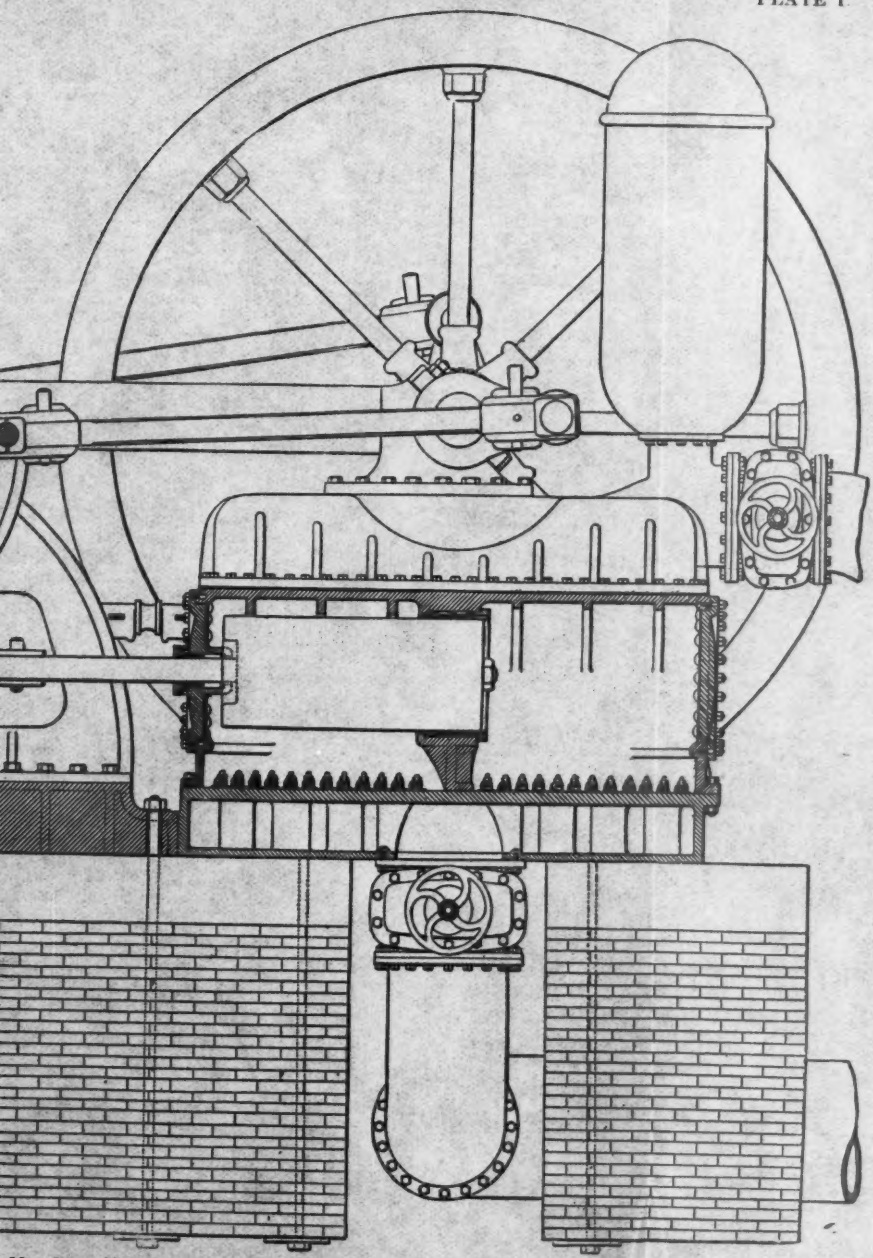
At the present time the Chestnut Hill High-Service Station is best known to the majority of our members and engineers in general.

Engines Nos. 1 and 2, designed and built by the Holly Manufac-

Fig. 1.



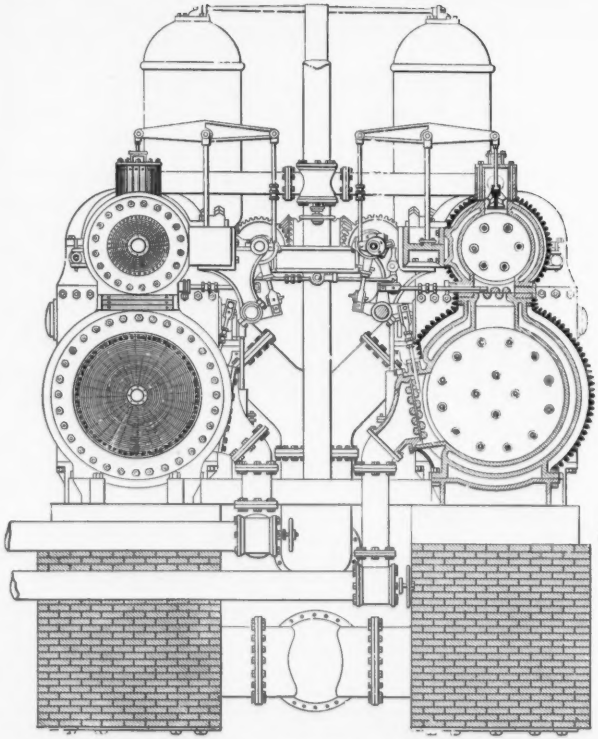
SECTIONAL ELEVATION, ENGINE No.



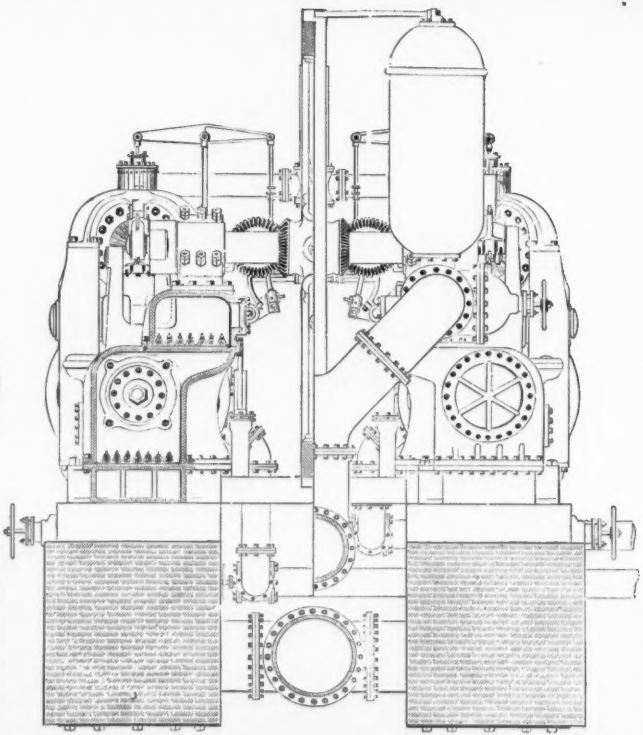
No. 1 or No. 2.

Fig. 7.

SECTION



ELEVATION AND SECTION, STEAM END.



ELEVATION AND SECTION, PUMP END.

ENGINE NO. 1 OR NO. 2.

PLATE II.

turing Company, Lockport, N. Y., were erected in 1887, and they were tested in August and September, 1888. Plate I shows a longitudinal section, and Plate II, cross sections of these engines. Boilers Nos. 1 and 2, of the return tubular type, designed by the City Engineer's Department of Boston, and built by George Miles, Boston, were used for supplying steam. The engines fulfilled the builder's guarantee for economy, and the boilers, including feed water heater, on a subsequent test, December 4 and 5, 1890, made a record of 12.14 pounds of water evaporated per pound of coal from

TABLE No. 2.—PRINCIPAL DIMENSIONS OF BOILERS.

Pumping Station.	Boilers.	Diameter (Feet and Inches).	Length (Feet and Inches).	Number of Tubes.	Size of Tubes (Inches).	Heating Surface (Sq. Ft.).
Chestnut Hill High Service.	No. 1	6′ – 6″	18′ – 6″	151	3	2 171
	No. 2	6′ – 6″	18′ – 6″	151	3	2 171
	No. 3	7′ – 6″	34′ – 4″	201	3	3 000
	No. 4	7′ – 6″	34′ – 4″	201	3	3 000
Chestnut Hill Low Service.	No. 5	8′ – 2″	24′ – 11⅝″	378	2	2 897
	No. 6	8′ – 2″	24′ – 11⅝″	378	2	2 897
	No. 7	8′ – 2″	24′ – 11⅝″	378	2	2 897
Spot Pond.	No. 8	7′ – 8″	26′ – 11¾″	256	2¼	2 295
	No. 9	7′ – 8″	26′ – 11¾″	256	2¼	2 295
	No. 10	7′ – 8″	26′ – 11¾″	256	2¼	2 295
Arlington.	No. 11	4′ – 8″	18′ – 0″	60	3½	937
West Roxbury.	No. 12	3′ – 6″	8′ – 0″	85	1⅞	300
	No. 13	3′ – 6″	8′ – 0″	85	1⅞	300

and at 212°. That record has not, to the writer's knowledge, been equaled by the same type of boilers under similar conditions.

Next came the No. 3 engine, designed by E. D. Leavitt, M.E., and built by the Quintard Iron Works, New York.* This engine was new in design, and especially interesting on account of the unusually high steam pressure, 185 pounds per square inch, and the mechanically operated pump valves which make it possible to run at

*This engine was described by Mr. Leavitt in a paper entitled "A Few Examples of High Grade Pumping Engines," presented to this Association, June 15, 1894, and printed in the JOURNAL for March, 1895, Vol. IX, p. 163. Plates VII and VIII accompanying that paper illustrate engine No. 3, and Plate IX shows boiler No. 3.

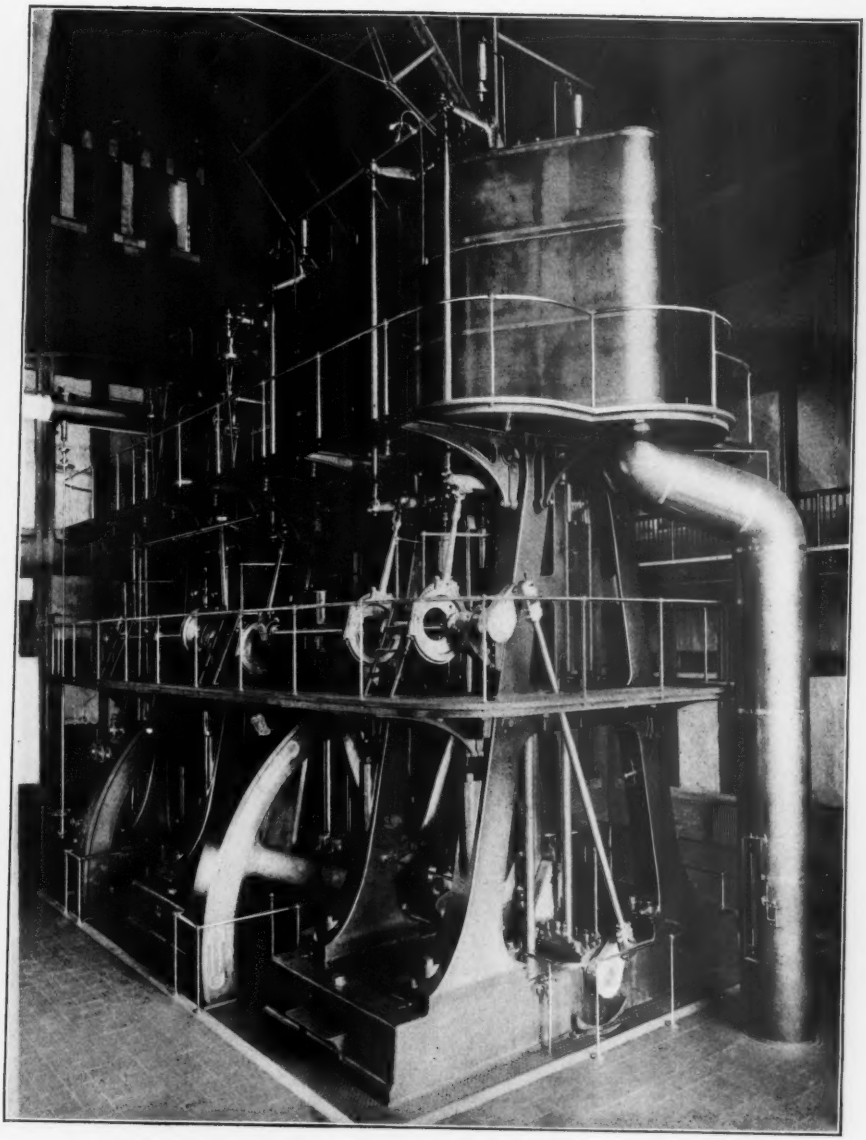
very high speed. This engine has been operated smoothly and economically at 70 revolutions per minute, the corresponding plunger speed being 490 feet per minute, or 40 per cent. in excess of the nominal contract speed. The conditions were such that it was necessary to design the engine to occupy a certain space in the existing building, which made the proposition rather more difficult than building an engine regardless of floor space. This engine was tested May 1 and 2, 1895, and had not, previous to the test, been run for more than seven consecutive hours. The engine had been very carefully built, and care exercised in aligning and erecting, but did not have the advantage of being limbered up by continuous running. However, under such unfavorable conditions, a record of 11.22 pounds of steam per indicated horse power per hour was established. Boiler No. 3, of the Belpaire type, designed by Mr. Leavitt and built by the Atlantic Works, East Boston, was used for supplying steam.

Table No. 3 gives the data and cost of operating the No. 3 engine for the year 1898.

TABLE No. 3.

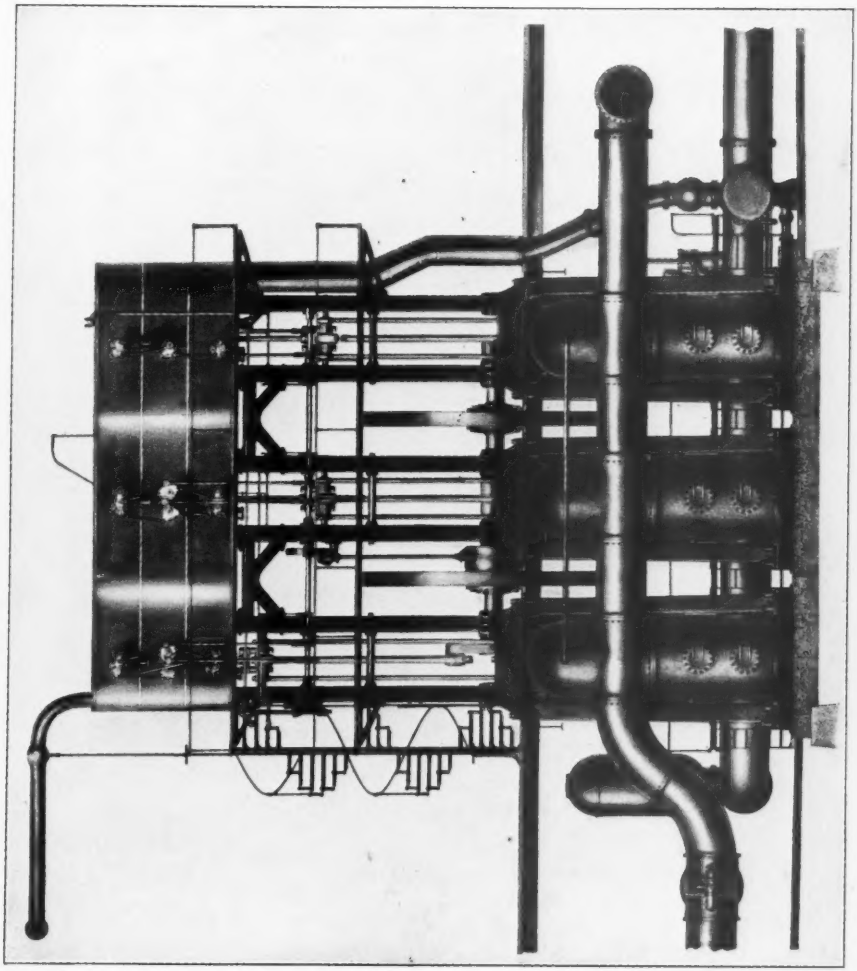
Data on Operation of Engine No. 3 at the Chestnut Hill High-Service Pumping Station for the Year 1898.

1. Total days run	365
2. Total hours run	8 542.5
3. Average hours run per day	23.4
4. Total gallons pumped (3 per cent. allowed for slip)	6 404 700 000
5. Average gallons pumped per day (3 per cent. allowed for slip)	17 547 000
6. Average gallons pumped per day (plunger displacement)	18 073 000
7. Average head pumped against (feet)	126.81
8. Total coal burned	5 901 061 lbs.
9. Duty on total coal (slip allowed)	114 790 000
10. Duty on total coal (plunger displacement)	118 370 000
11. Coal: Georges Creek, Cumberland, and New River.	
12. Cost of coal per ton (2240 lbs.)	$3.69
13. Total ash and clinker	425 278 lbs.
14. Per cent. ash and clinker	7.2
15. Pounds of coal to raise 1 000 000 gals. 126.81 ft. high	921
16. Cost of coal to raise 1 000 000 gals. 126.81 ft. high	$1.52
17. Pounds of coal to raise 1 000 000 gals. 1 ft. high	7.26
18. Cost of coal to raise 1 000 000 gals. 1 ft. high	$0.01
19. I. H. P. of engine	446
20. Coal per I. H. P. per hour	1.55 lbs.

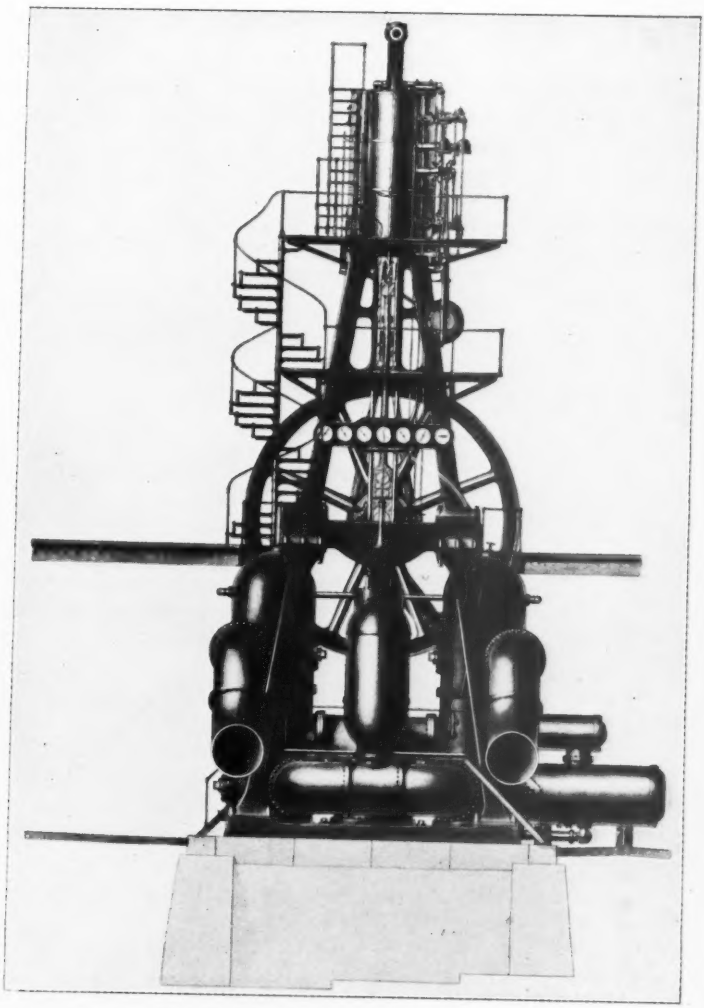


PUMPING ENGINE NO. 4. CAPACITY, 30 000 000 GALLONS PER DAY.

PLATE IV.



PUMPING ENGINE NO. 5, 6, OR 7. SIDE ELEVATION.



PUMPING ENGINE NO. 5, 6, OR 7. END ELEVATION.

21. Cost of coal per I. H. P. per year, running 24 hours per day (365 days, calendar year) $22.37
22. Cost of yearly H. P., running 24 hours per day (total maintenance) $47.72

The next engine was No. 4, designed and built by the Edward P. Allis Company, of Milwaukee, Wis. (see Plate III). This engine was also designed for a steam pressure of 185 pounds per square inch, and on the official test, May 1 and 2, 1900,— six years to a day after the test of the No. 3 engine, — made a new record of 10.479 pounds of steam per indicated horse power per hour. On this test the No. 4 boiler, including economizer, evaporated 12.478 pounds of water per pound of coal from and at 212°. This boiler is also of the Belpaire type, and was designed by Mr. Leavitt and built by the Lake Erie Boiler Works, Buffalo, N. Y. It is equipped with American mechanical stokers. A duty of 169 000 000 foot pounds for every 100 pounds of coal burned is not an uncommon weekly duty for the No. 4 engine when supplied with steam from the No. 4 boiler. Conditions are such at this station that records can be kept absolutely, without having to make allowances for auxiliary machinery. The credit for this economy is due not only to the combination of good engine design, good boilers, stokers, and economizers, but a considerable share of it belongs to the station corps of engineers and firemen.

There cannot at the present time be anything said concerning the economy of engines Nos. 5, 6, and 7 at the low-service station, and engine No. 9 at Spot Pond, which were designed and built by the Holly Manufacturing Company, of Lockport, N. Y., as none of them has been officially tested. However, it may be said that these engines have all been running several months, and each engine was turned over to the station corps of engineers to operate in less than twenty-four hours after the first start. They are all vertical triple-expansion engines, of the self-contained type (see Plates IV and V).

Engine No. 6 was started first at 4.20 P.M., July 2, 1900, and was operated by the contractor's men until 8 A.M. the following morning, when it was turned over to the station engineers; and beginning July 5, it was run continuously for twenty-four days. It was then stopped to put on the lagging.

The specifications for the low-service engines required the contractor to guarantee 145 000 000 foot pounds duty for each 1 000 pounds of commercially dry steam used by the engine and its auxiliaries

when delivering 35 000 000 gallons of water in twenty-four hours against a dynamic head of 45 feet, with a steam pressure of not more than 150 pounds per square inch at the throttle. This is the highest duty ever specified under similar conditions to the knowledge of the writer, and has not yet been accomplished by any engine officially tested.

The pumps are of special design, and the first of the kind built. Although these engines have not been officially tested, the weekly station duty indicates that the guarantee will be fulfilled, and there may be a little to spare. The highest weekly station duty thus far recorded on 100 pounds of coal is, in round numbers, 134 000 000 foot pounds. The boilers for supplying steam to engines Nos. 5, 6, and 7 were designed by Messrs. Dean & Main, of Boston, and built by the Atlantic Works. They are of the vertical fire tube type, and are expected to give very good results.

It may be fair to assume that the boilers are now evaporating, under actual conditions, nine pounds of water per pound of coal; on this basis the engines are doing about 149 000 000 foot pounds duty on the basis of 1 000 pounds of steam.

Engine No. 9 at Spot Pond is similar in design to engines Nos. 5, 6, and 7. The contract head is 125 feet, and the specified duty 150 000 000 foot pounds for each 1 000 pounds of commercially dry steam. This engine is expected to exceed the guaranteed duty considerably.

The boilers at this station are of the same type as those at the low-service station. They were designed by Dean & Main, and built by the Lake Erie Boiler Works, of Buffalo, N. Y.

The No. 8 engine was designed by Mr. Leavitt, and built by the George F. Blake Manufacturing Company for the Boston Water Works, and was originally erected at the Mystic Pumping Station, and subsequently moved to Spot Pond. This engine was described by Mr. Leavitt in the paper already referred to, and is illustrated in Plate VI accompanying that paper. Some slight alterations have been made to adapt the engine to the new conditions.

Engines Nos. 10, 11, 12, and 13 are of the standard types built by the George F. Blake Manufacturing Company.

SERVICE BOXES.

[*A General Discussion at the Meeting of November 14, 1900.*]

The President.* The topic for discussion this afternoon is service boxes, and we would like to learn from the members what they regard as an ideal service box from the superintendent's standpoint; one that is available in summer as well as in winter, one which can be placed with safety in a curbed street as well as in the outside limits of the city, and one that is easily accessible at any time. I will call on Mr. Martin, of South Framingham, for his idea of an up-to-date service box.

Mr. A. E. Martin.† Mr. President, I think you have called on a poor man for information on this subject. I have always used the Bingham & Taylor box. I do not consider it an ideal one by any means, but it is the only box I have ever used, although a good many different service boxes have been sent to me. I think you had better call upon somebody who has had more experience than I have.

The President. Possibly Mr. Walker, of Manchester, can give us some light. It is a good while since we have heard anything from the Granite State.

Mr. C. K. Walker.‡ I can't give you any light to-day, I am afraid. My lamp is hid under a bushel.

The President. You can tell us what kind of service box you use in Manchester.

Mr. Walker. I guess I use the same kind that almost everybody does, — the telescopic kind, made in the first place by "Jerekiah" Hayes, out in Erie, Pa. It is a simple concern, with a handle coming up within about a foot of the top. You don't very often have to use them, but if you don't have them well located in the winter time it makes some hard feeling. If they are well located, however, they are easily got at, and you can shut the water off when necessary.

---

* Byron I. Cook, Superintendent, Woonsocket Water Works.
† Superintendent, Framingham Water Company.
‡ Superintendent, Manchester Water Works.

I think it is the cheapest thing there is, because it does n't cost but a dollar, delivered complete. That is what we have been using for the last ten years. I have seen some patented devices, all good enough if people like them, but I have n't seen anything that suits me any better than the old kind. And you know it is a good deal with us as it is with the farmer; if he has a mowing machine that does the work well he sticks to that kind, although there may be a better kind. Our service box is cheap and satisfactory, and has done good service. I can't give you any further light on the subject, although I may say I have done some swearing when I could n't find a box, but that was n't any fault of the box; the box was all right.

THE PRESIDENT. Possibly Mr. Merrill, of Somerville, can give us some light with regard to a patented service box.

MR. FRANK E. MERRILL.* I came here to-day to see if I could n't find out what the ideal service box is, for I don't think I have got it yet. The box that we use has a cast-iron bottom and telescopic top, made of two-inch plain pipe, with an iron top which screws on, and a cover that is secured by a brass nut. (See Fig. 1.) We make up the boxes in our own shop, as we have the opportunity, and the cost is light. As Mr. Walker says, the ordinary box is all right as long as you know where it is, and that, I think, is really the main point. Our covers have a beveled edge, so people are not apt to stub their toes on them. That is something we have to be very careful to prevent. Aside from that I don't know that our box is any better than many others, but it gives us good satisfaction.

MR. A. E. MARTIN. I should like to state, Mr. President, that I think we have one service box which is among the most expensive in the country. I should hope there were very few, at least, that ever cost a water company or a water department any more than that one cost us. The original price was something like a dollar and a quarter, but for the privilege of locating it in a certain place we paid one of our citizens about three hundred dollars. He asked for one thousand dollars, but we finally compromised the matter with him for about three hundred dollars. That service box stood up above the sidewalk just the thickness of my finger. A party came into my office one morning and informed me that a lady had fallen over the box the night before and sprained her arm so badly that probably we would have trouble about it. I immediately went out and located the box, and found that there was some question whether

* Water Commissioner, Somerville, Mass.

she stumbled over the box or the curbstone; but the doubt was, of course, on our side, for we would have to prove that she did n't stumble over the box, and so, in order not to have any more trouble about it, we settled the case before it had gone very far in the

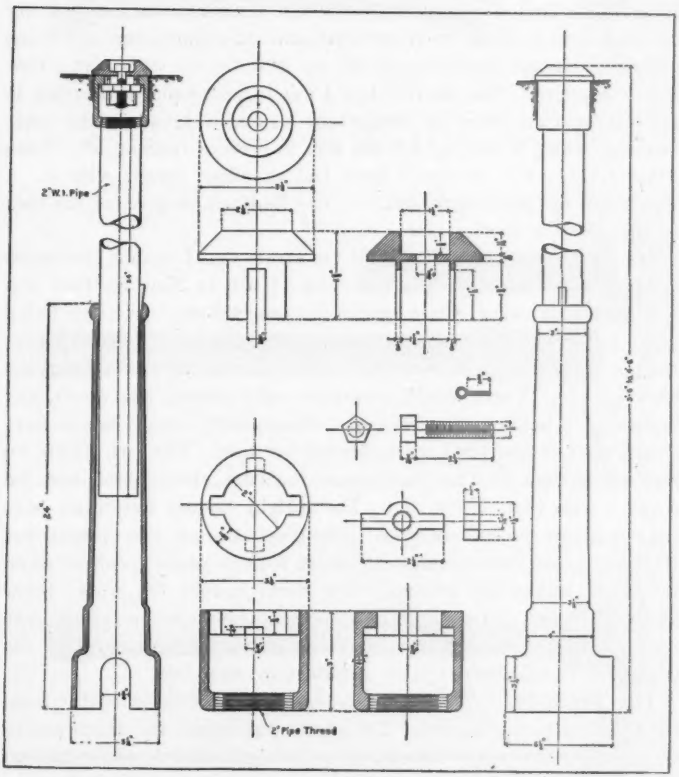


FIG. 1. — SERVICE BOX, SOMERVILLE WATER WORKS.

courts. The sidewalk was sloping, more so than is usual in most cases, and the lower edge of the box stood up, as I have said, just about the thickness of my finger. Mr. Merrill's statement that his boxes have a beveled edge brought this circumstance to my mind.

THE PRESIDENT. I will say in regard to the Bingham & Taylor

service box that the fault I find with it is that in some soils in the spring of the year the frost is liable to throw it, and it is often impossible to get it back into its original position without breaking it. A service box for use in such a soil must be telescopic, something which can be driven back again. Another trouble with the Bingham & Taylor service box is that the thread on the iron casting on the inside is liable to deteriorate, and in a short time the brass nut which clamps the cover to the top will fail to work and a new top is required. The service box I use is telescopic, with a slot in the side, and the cover is clamped by making a thread in the brass bushing, which is held by a brass wire to prevent running off. (See Plate I, Fig. 1.) So far I have had excellent results with it. I would call on Mr. Coggeshall, of New Bedford, to give us his idea in regard to a service box.

Mr. R. C. P. Coggeshall.* I am afraid that I cannot give much light upon the subject. The box now in use in New Bedford was designed some twenty years ago for our especial use. We had had a great deal of trouble from the very cause of which you have spoken, that is, lifting by frost. I have known a box to rise five inches above grade. Then, again, any one could remove the cover, and mischievous parties often did so; consequently many boxes were found more or less filled when needed for use. The box which we now use is made in three castings, — the base, the upright, and the cover. (See Plate I, Fig. 2.) The upright casting telescopes over the outside of the base casting. The frost may lift this upright, but it requires very little pressure to return it to its proper position when the frost leaves the ground. The cover covers the whole tube, and is fastened to the upright by a composition screw which goes through the cover and enters a composition nut fastened to the upright. It has been a very satisfactory stop box.

The President. We have a representative with us to-day from the Builders Iron Foundry. They have just begun the manufacture of a service box which they think is all right, and I would call on Mr. Connet for a description of it.

Mr. F. N. Connet. The model which I have before me is a model of the Stacy box, invented by one of your members. (See Fig. 2; also Plate I, Fig. 3.) One of the principal features about it is that it lacks some of the patented features of others. Many service boxes have the telescope joint threaded, and it has been

* Superintendent, New Bedford Water Works.

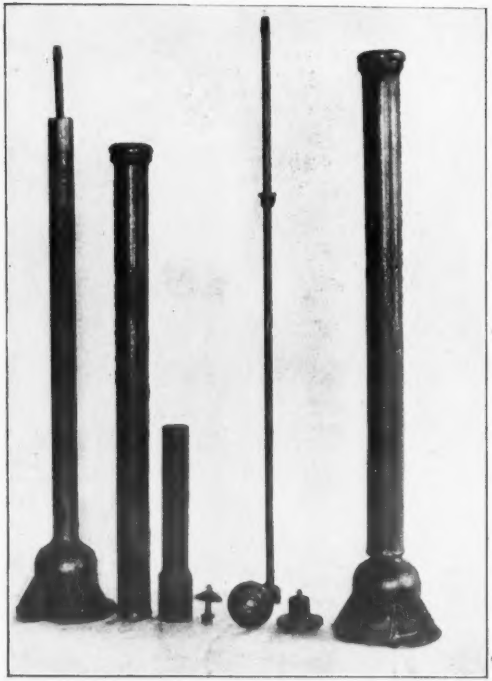


FIG. 1. — WOONSOCKET SERVICE BOX.

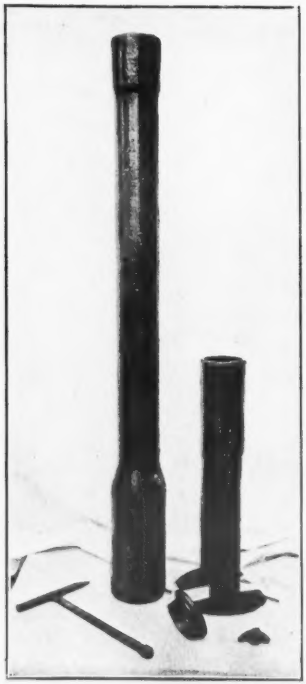


FIG. 2. — NEW BEDFORD SERVICE BOX.

FIG. 3. — STACY SERVICE BOX.

PLATE I.

found by many people that a heavy steam roller, or any heavy truck, passing over such boxes will invariably break them; and so we have improved ours by leaving off the thread and making the sliding joint of a plain, smooth, straight pipe, of wrought iron instead of cast iron. Another point is that many service boxes are made very light, — thinner castings are used for that purpose than are the castings for almost any other purpose that the water-works man comes in contact with; and so we have put in a little more cast iron, which we think is an improvement. Some of the other features may be imaginary advantages, — I can't say about that; but we have been told by a great many people that the corporation cock is apt to get misplaced, either to tilt sidewise or else to work endwise through the opening of the lower section. So this box is provided with a base or foot-piece, which is made so it will hold most of the corporation cocks in use to-day, and prevent them from rotating or moving endwise. This insures the cock being in line with the wrench. If the top section rises four or five inches in the winter time, you can hammer it down in the spring. The cap-screw is provided with a five-sided head, and cannot be turned by an ordinary wrench. These are the special features, but I would repeat that the sliding parts are made of wrought iron instead of cast iron.

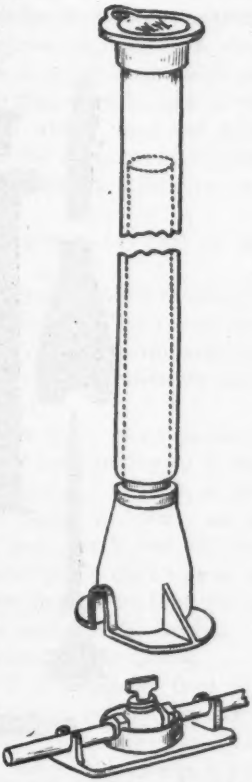


FIG. 2. — STACY SERVICE BOX.

A MEMBER. I should like to ask how much this costs?

MR. CONNET. The list price is two dollars.

THE MEMBER. Oh, I mean the net price.

MR. CONNET. We have to size a man up before we determine that. We will make a special discount of twenty per cent. to you, however.

THE PRESIDENT. We would like to hear from Mr. Holden.

MR. HORACE G. HOLDEN.* We use a box of our own design, which is in some respects like the Stacy box. That is, we have a casting at the bottom, which fits over the service pipe, and into this

FIG. 3. — SERVICE BOX MADE BY THE PENNICHUCK WATER WORKS, NASHUA, N. H.

casting is fitted a one-inch plain iron pipe about four feet long (Fig. 3). Over this pipe is a telescopic casing eighteen inches long, which we can raise or lower to conform to the grade of the street. We have a rod which straddles the cock, and comes up into this pipe about half-way. We use a wrench made from a half-inch rod split at one end,

* Superintendent, Pennichuck Water Works Company, Nashua, N. H.

which we can drop right down and be sure of striking the extension rod. You can open or shut the cock without any trouble, and are always sure to hit right upon it. The material costs us about sixty cents for each box. We don't count the labor of making the boxes as anything, because the men put them together on rainy days, when they have nothing else to do. We seldom have any trouble with the boxes. The frost will occasionally raise them a little, and in the spring of the year a man has to go round with a maul and drive some of them down; and in case the earth has got over any of them so they are covered, it is very easy to raise them up a little to conform to the grade.

THE PRESIDENT. Mr. Bancroft, can you give us any light on the subject of service boxes?

MR. LEWIS M. BANCROFT.* Mr. President, I don't know as I can give you any light. We use the Bingham & Taylor box, and we have one expensive one like Mr. Martin's. They will come up sometimes in the spring, and people will find them when we don't want them to.

THE PRESIDENT. Those of us who went to Syracuse probably observed, in passing about the city, service boxes sticking up in the sidewalk anywhere from one to two or three, and I think in a few cases as much as six inches. I know I made an inquiry as to whether there was n't any fault found at that, and I was told no, that it did n't make any particular difference; people did n't seem to care much about it. But I find that in New England we have got to have them flush with the sidewalk, or else there will be trouble.

I would like to ask Mr. Tower, of Cohasset, for his opinion.

MR. D. N. TOWER.† Mr. President, I have always used the Bingham & Taylor box, and I have had the same trouble you spoke of from their being thrown up by the frost. We used to use a 93 E box, which could be extended to three and one-half or four feet, but now we buy a size larger, a 93 B box, which opens a foot longer; and before setting the box we take a chisel and cut the thread off the lower section. That makes a regular telescopic box of it and prevents its being thrown up, and I like it very much. I have n't heard of anybody else doing that, and I thought it might be something new.

MR. CONNET. I have been told by the superintendent at Burling-

* Superintendent, Reading (Mass.) Water Works.
† Superintendent, Cohasset Water Company.

ton, Vt., that they do the same thing there that Mr. Tower does, — chip off the thread.

Mr. George E. Winslow.* I cannot speak from present experience, Mr. President, but I can from the past. We used to use the Bingham & Taylor box, and before that, they used a cast-iron riser and a cast-iron sliding part at the top. The cover was an ordinary plug which could be kicked off or picked up very easily. If it was put flush it left the joint about an inch below the sidewalk, and the children would pick the covers off and fill the boxes with stones and gravel and sand, which caused us great inconvenience; so we adopted the Bingham & Taylor box and substituted them wherever we were obliged to remove the old ones. The Bingham & Taylor boxes have worked very well in Waltham, for most of the soil there is sandy or dry gravel, and it is very seldom that one of the boxes is raised by the frost. The feature of it which permits of its being adjusted to any height I think is very valuable. But in some parts of the city the soil is clayey or marly, in some cases, and loamy, and in such places the frost would raise the tops sometimes five or six inches above the surface; and there the Bingham & Taylor box did n't work well. The first season we could go along with an ordinary wooden tamper and tamp them down, but the next season we could n't do it. So after that I used to cut off the thread, as has been spoken of, — that is, on the riser part, — and put the top part over; and then if it was raised by the frost we could tamp it down easily. The Bingham & Taylor box is really the one that I like better than any other we tried.

The President. There is another trouble with the Bingham & Taylor box that I have found, especially in streets that are not curbed. That is, if a team drives along and strikes the edge of the cover, it either breaks the first piece or else breaks the nut off in the casting; and a box that has the cover clamped in the center never has that trouble.

I will call on Mr. Thomas, of Lowell.

Mr. Robert J. Thomas.† Mr. President, the box I use (see Fig. 4) is a plain telescopic box of wrought-iron tubing. On the bottom is a casting which fits our sidewalk cocks. We make our own sidewalk cocks and make them so this casting fits right on. We very rarely have any trouble in getting the wrench on the cock, and there is no chance for any dirt to get in around the handle of the cock, which

* Waltham, Mass. † Superintendent, Lowell Water Works.

is tapered so that the wrench readily strikes the key. On the top we have another casting with a plug in it, which is also fastened so it requires a big wrench to unfasten the plug. The advantage which we claim for this box, which is made in Lowell, is that, being of wrought-iron tubing, it is hard to break. The Bingham & Taylor box is easily broken, and the other boxes which are made of cast iron have to be handled carefully or else they will break. But you can put ours in the ground anywhere and they won't break; and, making our own cocks as we do, it is an advantage to have them made so that this casting fits very snugly upon the cock. The box has a rounded top.

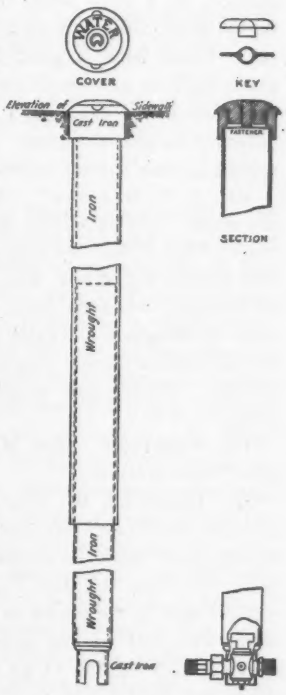


FIG. 4. — LOWELL SERVICE BOX.

I am surprised that in Somerville, that being a temperance city, they should have any trouble in having to settle for damages to people from tumbling over the boxes. We never had a case of that kind in Lowell, — and we have license there, too. We don't have to tie a brass wire to the top to keep it from running off. We used to use a box with a plug in the top of it, and frequently we would find the plug was gone, that children had picked it up and carried it away.

I think the Stacy box is a good box, and if ours was n't made in Lowell I should favor the Stacy box, for I think it is the best box that I have seen on the market. As to the boxes in Syracuse, I was there at the time to which the President refers, but I did n't see any of them sticking up from the ground, and I don't see what was the matter with the President that he should have seen them.

THE PRESIDENT. I should like to know what they use in Natick.

MR. GEORGE W. TRAVIS.* We use about the same box as Mr.

*Superintendent, Natick Water Works.

Walker has described, of the telescopic pattern, and it works very nicely, except, of course, we have some trouble from the frost lifting it, but it is an easy matter to drive it down again.

The President. There seems to be a good deal of difference of opinion, as I have heard it expressed, among superintendents, in regard to the use of the extension rod, — whether the rod is useful or not. I have heard a good many say that it is apt to rust off, the pin is liable to get out of the stop-and-waste, and cause trouble that way; but I have used a rod for ten years and have never found any difficulty in that direction. I should like to hear from Quincy in regard to their service boxes.

Mr. J. F. Gleason.* We have used about all the boxes that are made. We have used the Taunton box, we have used the Bingham & Taylor box, we have used the M. J. Drummond box, and we now use the Coffin box, and I think this gives the best satisfaction of anything we have had. We have had a good deal of trouble with the Bingham & Taylor box. My idea of a service box would be one with a funnel-shaped top with the big end down into the ground. I think that would prevent it from being thrown by the frost.

The President. Has Mr. Gow, of Medford, anything to say about service boxes?

Mr. Frederick W. Gow.† We use the same box that Mr. Merrill uses, and, as he has said, it is not by any means an ideal box. Speaking of the bevel on the cover, I would say that it is n't safe to bank too much on that. The bevel on our box runs from five-eighths inch in the center to nothing at the edge, and we had a box which was flush on the side, which would leave the center of the cover up five eighths of an inch, and the city solicitor told me the other day he thought he could settle the case for three hundred dollars.

The President. I believe there is hardly a water department in New England but that has had some experience in that line. If any one falls anywhere in the vicinity of a service box, the box is always blamed for it.

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*Foreman of Construction, Quincy Water Works.
†Superintendent, Medford Water Works.

ON THE RISE AND PROGRESS OF WATER-SUPPLY SANITATION IN THE NINETEENTH CENTURY.

BY WILLIAM T. SEDGWICK, PROFESSOR OF BIOLOGY IN THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

[*Presented February 13, 1901.*]

At a time when men of art, science, and literature are recalling the accomplishments of a century of wonderful activity and progress, it is fitting that the New England Water Works Association should also pause for a moment and review at least one aspect of the advancement which has been made within the century in its own peculiar field.

Few sanitarians even realize how recent are our modern ideas of water-supply sanitation. The clear recognition of water as a vehicle of infectious disease dates no further back than fifty years, and our methods of water purification so far at least as these may be called scientific and not purely empirical may be said to have grown up since 1886. There can be no doubt that epidemics due to infected water supplies had frequently decimated the human race during the long roll of the centuries that preceded the nineteenth, and yet mankind had continued in almost complete ignorance of its imminent danger from this source. If we ask how it happened to be left for the nineteenth century to teach us the great sanitary lesson that water is one of the most dangerous vehicles of infection, we shall probably find the answer in the fact that it is only in this century that careful scientific investigation of the natural history of disease has ever reached a high level. Modern sanitarians have been more fortunate than their predecessors simply because they have been more scientific.

At the beginning of the nineteenth century there was no such thing as water-supply sanitation. There were water supplies in abundance as there had been water supplies from time immemorial, but sanitation was something as yet hardly begun, and sanitation as applied to water supplies did not arrive until long after it had come in certain other directions. The occurrence of lead in drinking-water, for example, had long been known, and lead-poisoning was a subject

upon which a certain amount of knowledge had been collected, yet one of the most notable epidemics of lead-poisoning in a water supply occurred in the nineteenth century and was not only carefully studied, but happened to be so connected with royalty as to have attracted universal attention. As this case, though often referred to, is seldom cited in such a way as to be instructive to the modern sanitarian, I may venture to refer to it in some detail.

LEAD-POISONING IN THE FAMILY OF LOUIS-PHILIPPE.

Louis-Philippe and his family established themselves, after his abdication in 1848, on an estate in England known as Claremont; and although for some thirty years the water supply of the palace of Claremont had been drawn from a spring through lead pipes it had never been suspected of causing any trouble. After the arrival of the French royal family, however, lead-poisoning appeared in a very serious form among many of the inhates, and the case naturally attracted wide attention. A report upon it was made by Dr. H. Gueneau De Mussy, a distinguished French physician who attended the family, and may be found in the *Dublin Quarterly Journal of Medical Science, Vol. VII, for 1849.*

After having given a careful clinical account of the Claremont cases of lead-poisoning, of which there were thirteen out of thirty-eight persons in or about the palace, and after remarking that "the malady has shown no respect for condition and attacked indiscriminately servants, aides-de-camp, and princes, and did not spare even the most august and pious of victims," Dr. Gueneau De Mussy proceeds to describe the water supply of the palace as follows: —

"The spring that furnishes the palace of Claremont with water issues from a sand-bed at about two miles distance. It was chosen for its uncommon purity from among a great many others in its vicinity and the water was, thirty-three years ago, conducted to the palace through leaden pipes. In the present day some other metal would, perhaps, have been selected, for experience has taught us that pure water, and especially distilled water, acts rapidly on lead when it comes in contact with it. . . .

"The water of the palace of Claremont had been for many years employed by its inhabitants without any bad result; how was it, then, that this water, till now harmless, had become suddenly a violent poison? This is what has puzzled me and everybody else; and although I looked for its cause with the greatest attention, I could

discover only a single alteration, apparently of little importance, lately made in the transmission of the water.

"Until about eleven months ago, leaden pipes used to take up the water from a large natural cistern near its source. When the present occupants of the palace came to live in it, they wished to preserve this natural cistern from the vegetable and animal detritus that usually fell in it. For this purpose an iron cylinder of six feet diameter and twenty feet high was constructed and sunk into the ground fifteen feet deep. The water swelled up within, and a leaden pipe was attached to it with a funnel-like mouth projecting by a few inches in the inside of the cylinder, which was closed at the top by an iron cover with several holes in it to allow the air to make the requisite pressure on the surface of the water. You may discover what has been the influence of this change; for myself I think it has been the origin of all the evil. The datum is certain, but I have only hypothesis to offer as to the chemical reaction of the water. . . .

"The water of the iron cylinder did not contain any lead; that of the pipes contained some and that of the cistern [the leaden cistern in the palace in which the water naturally stood for some time] contained much more of it. . . .

"Professor Hoffman has ascertained the quantity of metallic lead in the water and has found that it amounted to a grain per gallon, an enormous quantity when we consider that the poisoned water was used in all culinary and table purposes, and, previously to the discovery of its deleterious character, even in the preparation of tisans and lavements."

This is not only one of the most famous, but also one of the most impressive cases on record, touching the conveyance of lead by drinking-water. From our present point of view it seems reasonable to suppose that the change from an open "cistern," in which the water was probably well aerated, to a closed iron cylinder with only a few holes in the cover, was sufficient to cause the retention of enough free carbonic acid to explain the result. I hardly need refer to the recent experience of the city of Lowell, in which a public water supply rich in free carbonic acid proved to be a dangerous solvent of lead.

PURE WATER SUPPLIES AS VEHICLES OF POISONOUS METALS.

In connection with water as a vehicle of lead ought always to be mentioned Professor Drown's discovery of the possibility of the

similar conveyance of copper by water supplies charged with free carbonic acid. The case was that of a prominent family having a summer home near the Blue Hills in Milton, Mass. Members of the family were found to be suffering from obscure poisoning of some sort which was finally proved to be due to copper. Professor Drown discovered that the water supply of the house was derived from a spring on an uninhabited hillside, and that the water, while otherwise above reproach, was so rich in free carbonic acid that it readily attacked copper. Within the house, brass instead of lead connections had been used, and the result was a slow and insidious poisoning of the family by means of copper conveyed by water. The results of Professor Drown's studies in connection with this case, and the more recent epidemics of lead-poisoning in Lowell, Mass., and elsewhere, traced by the chemists of the State Board of Health to the action upon lead pipes of a relatively pure ground-water containing free carbonic acid in excess, constitute a distinct and important advancement within the century in our positive knowledge of the dangers of water supplies as possible vehicles of poisonous metals or solutions of their salts. (*See Thirty-First Annual Report, State Board of Health of Massachusetts, 1899, pp. xxxi and 26.*)

THE TARDY RECOGNITION OF WATER AS A VEHICLE OF INFECTION.

The fact that a water supply may under certain circumstances become a vehicle of the germs of infectious disease is a discovery of the latter half of the nineteenth century. "That a certain connection exists between the use of impure water and the spread of pestilential disease is a circumstance that has been observed from the earliest times," but this observation, being only of a loose and general character, had not prevented the almost universal use of more or less impure water supplies for domestic purposes even much later than 1850. The sanitary condition of the water supply of London during the cholera epidemic of 1854 will shortly be described. It was not very much better during the next great cholera outbreak, in 1866. Almost at the end of the century, in 1892, the cholera test proved conclusively that the water supply of Hamburg, one of the largest and most important commercial cities of Germany, was highly impure. The water supplies of Paris, Philadelphia, Washington, Chicago, St. Louis, Pittsburgh, and many smaller cities still remain more or less impure even at the end of the century. It will always be one of the sanitary paradoxes of the "wonderful century" that some of the most

progressive cities of the United States acting on the honest, intelligent, and expert advice of the ablest contemporary engineers, even as late as the seventies introduced water supplies derived from obviously polluted rivers or lakes and delivered, directly to the people, polluted water without previous purification of any kind. This was the case, for example, at Chicago, — where the water supply was originally derived from an intake distant only one mile from the lake-front and subject to pollution not only from sewers on that front but also at times from the discharges of the then very foul stream, the Chicago River; at Pittsburgh, — where the water of two highly polluted rivers was chosen as the source of supply; at Lowell and Lawrence, Mass., — which as late as 1872 turned without hesitation to the highly polluted Merrimac; at Burlington, Vt., — where in 1867 water began to be drawn from Lake Champlain at a point less than a mile from the outfall of the main sewer into the same lake; and at many other places.

QUIET WATER — NOT RUNNING WATER — PURIFIES ITSELF.

The reason for this practice, now so thoroughly discredited, was as is well known an undue reliance upon the so-called "self-purification of streams," a process which, though often real, is often also incomplete and untrustworthy. The idea prevalent in the greater part of the century that "running water purifies itself," while true enough up to a certain point and especially true so far as purification by dilution and by the displacement of dissolved gases is concerned, has in the last years of the century been shown to be either erroneous or to have little or no meaning so far as the direct oxidation of organic matter or the destruction of many living microbes which may be present in suspension are concerned. For these latter, on the contrary, it would probably be more correct to say that "quiet water purifies itself," since in such water microbes tend eventually to disappear, either dying from old age or inanition or settling to the bottom and being there detained.

SANITARY CONDITION OF THE LONDON WATER SUPPLY IN 1837.

It is universally recognized and admitted that the distinction of leadership in sanitary progress in the nineteenth century rightfully belongs to England. It is interesting, therefore, to inquire what progress in water-supply sanitation had been made in the English

metropolis in the first half of the century. The following report, made by a physician in 1837, throws some light on the subject: —

"In no part of France, Würtemburg, Bavaria, Bohemia, Prussia, Saxony, the Confederated States of Germany, Holland, and Belgium is there a city in which, as in London, the general mass of filth of every description created by a vast population is first allowed to enter the river which may happen to traverse that city and is then returned, diluted with the water of that river, to the houses of the inhabitants to be used either for domestic or culinary purposes. Although by avoiding the latter disgusting alternative, foreign cities are less free from unpleasant smells than London is, in this respect it may be truly said that foreigners smell the filth of their cities but do not swallow it, whereas London swallows it but seldom smells it." (*Report of A. B. Granville, M.D., to the Board of Directors of the Thames Improvement Company, January 2, 1837.*)

THE WATER SUPPLY OF LONDON IN 1854.

The sanitary — or unsanitary — condition of the London water supply even as late as 1854 is described as follows in an official report: —

"The sources from which every Metropolitan Company, without exception at present, derives its supply are more or less impure. . . . The most impure, on the south side of the river, is the Southwark and Vauxhall water, taken at Chelsea Reach. This last water contains the *débris* of food derived from the water-closets and sewers of the metropolis. It also contains living organisms which naturally belong to brackish waters, which proves that a certain amount of tidal sea-water is supplied to the inhabitants of the district. Between it and the water of the Thames . . . there is frequently only that amount of difference which would arise from mere subsidence. The water is nearly always more or less opalescent; . . . the complaints made of this water are almost universal. . . . Nearly all the shallow well and pump-waters were of a very impure description. . . . The baths and wash-houses have been supplied with water of so bad a quality that they have become greatly disused. . . . Dr. Hassall says in regard to the Southwark and Vauxhall water that its use ought not to be permitted an hour longer than is absolutely indispensable. In several localities there is no water supply at all, the people either buying from water-carts, or taking water from the Thames, the Wandle, or even from ditches. . . . In Chelsea there are still a

great many places where the people are dependent upon bad wells or on the river." (*Report of Dr. Sutherland, Medical Inspector, to the General Board of Health, on Epidemic Cholera in the Metropolis in 1854.*)

DIFFERENCES OF OPINION CONCERNING THE RÔLE PLAYED BY IMPURE WATER IN THE CAUSATION OF DISEASE.

Such was in 1854 the sanitary condition of the public water supply of the metropolis of England, which country has been not only the pioneer but also the leader in sanitation in the century under consideration. It was at this time (1855) even actually doubted, by good authorities, that water is a vehicle of infectious disease, for it was held by many that, even when polluted, it was only a "predisposing," not a direct and sufficient, cause of disease. Dr. Sutherland, for example, in the report already referred to, while beginning his paper with the dictum quoted above, "that a certain connection exists between the use of impure water and the spread of pestilential disease is a circumstance that has been observed from the earliest times," remarks also that "there is a difference of opinion on the part which impure water plays in the phenomena," and continues: "It is believed by some that the water which induces cholera contains the specific poison of cholera in it, probably derived from the evacuations of cholera patients, while others believe that there is no sufficient evidence of this . . . and consider . . . that water containing putrescent organic matter acts as a very powerful predisposing cause . . . but not as a specific poison."

POPULAR PREJUDICE AGAINST PUBLIC WATER SUPPLIES.

In view of the uncertain attitude of experts towards water as a vehicle of infectious disease, and in view of the plainly unwholesome character of such public water supplies as that of London, it is not surprising to find some popular opposition to the introduction or extension of public water supplies. An amusing instance of such opposition was the following: "The sanitary works of Penrith were begun in 1853 and were completed in 1856; but recently, in 1862–63, they have been extended. The water supply was shortly found to be inadequate to the wants of the town, and much care was given to discover the cause of it. The higher districts of the town were especially ill supplied, and the want of pressure was supposed to be due to leakage. It was not until an extension of the water works,

at much expense, in 1862, that the cause of this inadequate supply was discovered, and then it proved to have been in existence since the beginning of the works in 1853. It was found that some logical and consistent opponent of the sanitary measures that were then being adopted had previously inserted into one of the water mains a five-foot pole and fixed it there with wedges. By degrees this pole had got accumulations round it and the water supply had become scantier and scantier." (*Dr. Buchanan, Water Supply of Penrith, Ninth Annual Report, Medical Officer of the Privy Council, pp. 173, 174. London, 1867.*) The fear of lead-poisoning from public supplies was apparently so great among some persons in Boston in 1849 (perhaps because of the contemporary Claremont epidemic) that some householders who desired, yet dreaded, to take the new Cochituate supply just then being introduced, employed glass-lined pipes for house connections.

ASIATIC CHOLERA IN LONDON IN 1854 AND THE LESSONS OF THE BROAD-STREET WELL.

Enough has now been said to show not only that water-supply sanitation had no existence in the first half of the nineteenth century, but also that experts as well as the people at large were still in doubt and perplexity as to the part played by polluted water in the propagation of infectious disease. Before water-supply sanitation could be seriously considered and developed, the necessity and the reasons for it had to become more clear. And after the middle of the century both the necessity and the reasons soon became apparent. Even as Dr. Sutherland was writing his report, there appeared a brief paper on a curious concentration of cholera cases about a polluted well in Broad Street, London, which to many of those most competent to judge seemed to establish beyond peradventure the theory that a public water supply might be not only the predisposing cause but the direct and ready vehicle of the specific poison of Asiatic cholera.

London was still abundantly supplied with wells and pumps in or near the public streets when the cholera again appeared in the city in 1853. One of the principal parishes of the city, that of St. James, Westminster, had suffered somewhat during the cholera epidemics of 1832 and 1848 and now suffered once more in 1853 but on the whole rather less, relatively, than the rest of London. In 1854, however, the reverse was the case, the Cholera Inquiry Committee

having estimated that "in this year the fatal attacks in St. James Parish were probably not less than 700" on an area of 164 acres and among a population of about 37 000. Careful study showed further that a very large part of this mortality was localized within a particular district of the parish, the remaining districts showing no special excess of cholera-mortality above the rest of London. Attempts were made to find a cause for this local excess in peculiar geographical and atmospheric conditions; in "a previous long-continued absence of rain"; in "a high state of the temperature both of the air and of the Thames"; in "an unusual stagnation of the lower strata of the atmosphere highly favorable to its acquisition of impurity," and in the combination of these and other "factors"; but the Inquiry Committee perceived that "the resulting mortality was so disproportioned to that in the rest of the metropolis and more particularly to that in the immediately surrounding districts that we must seek more narrowly and locally for some peculiar conditions which may help to explain this serious visitation."

Fortunately, at the very beginning of the outbreak of cholera in the district, Dr. John Snow, with a novel and highly commendable curiosity, had taken the trouble to learn the number and exact location of the fatal cases, as is stated in his own report to the Cholera Inquiry Committee: —

"I requested permission on the 5th of September to take a list at the General Register office of the deaths from cholera . . . and I made inquiry in detail respecting the eighty-three deaths registered. . . . On proceeding to the spot, I found that nearly all had taken place within a short distance of the pump in Broad Street."

This is not the place to give a detailed account of the remarkable outbreak which Dr. Snow studied with so much modesty, care, ability, and success. It suffices for our present purpose to state that further investigations by Dr. Snow and by others seemed at the time to prove, and are now universally admitted to have established, the fact that a polluted and infected drinking-water was in this case not merely a predisposing factor of disease but the effective vehicle of the poison peculiar to the disease, which poison actually produced the excess of Asiatic cholera plainly visible in the immediate vicinity of the well on Broad Street from which the water containing the poison was drawn. Close study revealed not only the fact that all, or very nearly all, of those in the vicinity who suffered from cholera had used the water from the pump in question, while those who escaped

had not used it, but also some very remarkable instances of cholera among persons living at a distance who had by accident or design drunk of the water from this well, and afterwards had the disease, although no cholera cases appeared among their neighbors for miles around. Between August 19 and September 30, 1854, no fewer than 616 deaths from Asiatic cholera are recorded by Dr. Snow as having occurred in the vicinity of the Broad-street pump. In Broad Street alone, containing only 49 houses and but 896 inhabitants, there were 90 deaths from cholera, as was learned by a careful house-to-house inquiry conducted by the Rev. Mr. Whitehead. A further investigation by Mr. J. York, a surveyor and the secretary to the Inquiry Committee, showed that the well which was incriminated was situated only three feet from a cesspool used by the family at No. 40 Broad Street, and that this cesspool had for some time been overflowing and leaking directly into the well. Also, that certain cases of diarrhœa, probably choleraic in character, had occurred in the house No. 40, just before the terrible outbreak of cholera among the users of the water. (*Report on the Cholera Outbreak in the Parish of St. James, Westminster, during the Autumn of 1854. London, J. Churchill, 1855.*)

DIFFERENCE OF OPINION AMONG EXPERTS AS TO THE CAUSE OF THE BROAD-STREET EPIDEMIC.

To show how little agreement existed in 1854 even among experts as to the probability that drinking-water could serve as a ready vehicle of disease, it is worthy of notice that a Committee for Scientific Inquiries in relation to the cholera-epidemic of that year, composed of five eminent persons, of whom two, Dr. (now Sir) John Simon and Dr. William Farr, were among the most competent sanitary experts of the time, reported concerning this epidemic under date of July 14, 1855, to the President of the General Board of Health, as follows: —

"That such local uncleanliness prevailed most intensely throughout the suffering districts is evident from the reported results of house-to-house visitation. The exterior atmosphere was offensive with effluvia from ill-conditioned sewers; the houses were almost universally affected in the same manner, partly from the same source, partly from their own extreme defects of drainage and cleanliness, partly from unregulated slaughtering and other offensive trades; the

inhabitants were overcrowded, perhaps to the greatest degree known even in London; and the general architecture of the locality was such as to render it almost insusceptible of ventilation. . . .

"Why, however, this district should have suffered in marked disproportion to many other districts, hardly, if at all, superior in their sanitary arrangements; or why, generally, it should be the tendency of cholera in its visitation to select particular foci for extreme outbreaks, instead of diffusing itself more equally over all ill-conditioned districts, is a difficulty which hitherto we have no scientific material to solve. . . .

"In explanation of the remarkable intensity of this outbreak within very definite limits, it has been suggested by Dr. Snow that the real cause of whatever was peculiar in the case lay in the general use of one particular well, situate at Broad Street in the middle of the district, and having (it was imagined) its waters contaminated with the rice-water evacuations of cholera patients.

"After careful inquiry, we see no reason to adopt this belief. We do not find it established that the water was contaminated in the manner alleged; nor is there before us any sufficient evidence to show whether inhabitants of the district, drinking from that well, suffered in proportion more than other inhabitants of the district who drank from other sources.

"There is mentioned, however, a remarkable instance in which it seems probable that the water of this well did really act as a vehicle of choleraic infection; but (assuming the absence of fallacy in the case) this probability might easily be admitted, without its therefrom resulting that infection depended on the specific material alleged. The water was undeniably impure with organic contamination; and we have already argued that if, at the times of epidemic invasion, there be operating in the air some influence which converts putrefiable impurities into a specific poison, the water of the locality, in proportion as it contains such impurities, would probably be liable to similar poisonous conversion. Thus, if the Broad Street pump did actually become a source of disease to persons dwelling at a distance, we believe that this may have depended on other organic impurities than those exclusively referred to, and may have arisen, not in its containing choleraic excrements, but simply in the fact of its impure waters having participated in the atmospheric infection of the district." (*Report of the Committee for Scientific Inquiries, etc., pp. 51 and 52. London, 1855.*)

ASIATIC CHOLERA IN A LONDON WATER SUPPLY IN 1866. RISE OF THE GERM THEORY OF DISEASE.

It is easy to perceive from a perusal of the foregoing statements that in 1855 the very basis of water-supply sanitation had yet to be laid even in that country which has been, during the nineteenth century, the acknowledged leader in both the theory and the practice of sanitation. The cholera epidemic of 1866, however, furnished a striking demonstration of the fact that a sewage-polluted water may become the effective vehicle of the actual poison of disease; for during this epidemic it was clearly established that the cholera was in excess within the precise limits of distribution of drinking-water by one of the Metropolitan Water Companies which, though supposed to be filtering its supply, did as a matter of fact distribute to its patrons unfiltered water which had apparently been infected with the excrements of cholera patients. (*See Report of J. N. Radcliffe, Ninth Annual Report, Medical Officer of the Privy Council, London, 1867; also Rivers Pollution Commissioners, Sixth Report, p. 144.*) There is good reason to believe, however, that the cause of this epidemic would likewise have been attributed by many to mysterious predisposing influences, such as atmospheric conditions, climatic changes, or other factors, had it not been for the circumstance that during the decade in which the epidemic occurred a new and helpful theory of the precise cause of infectious disease had sprung up in consequence of the epoch-making researches of a French mineralogist and chemist, then little known, but destined to become, shortly, one of the most famous workers in the annals of the nineteenth century; namely, Louis Pasteur, who had then recently established both the germ-theory of fermentation and the germ-theory of the diseases of wine and beer. Already it was more than suspected that the infectious diseases of man and the lower animals must likewise be due to living germs, and when the next serious epidemic which appeared to be due to a polluted water supply occurred, namely, the Lausen epidemic of typhoid fever in 1872, the germ-theory of infectious disease, though not yet fully established, had already won popular recognition and had become even among experts an accepted working hypothesis which had the great merit of furnishing a ready explanation for many of the obvious facts of epidemiology, and accordingly proved a powerful support for what was now called the "drinking-water theory" of infectious disease (*Trinkwasser Theorie*).

AN EPIDEMIC OF TYPHOID FEVER IN LAUSEN, SWITZERLAND, TRACED TO AN INFECTED PUBLIC WATER SUPPLY.

The epidemic in question may be said to have been the turning point in favor of the theory that impure drinking-water may be not only a predisposing cause, but the actual vehicle of the *materies morbi* of infectious disease, and, as might have been expected, the battle between the two camps was hotly contested. Now that the smoke of it has disappeared, it is easy to see that the victory belongs undoubtedly to those who held the *Trinkwasser Theorie*. The epidemic occurred in the little village of Lausen in the Canton of Basel in Switzerland in August, 1872. Lausen was a well-kept village of 90 houses and 780 inhabitants, and had never, so far as known, suffered from a typhoid epidemic. For many years it had not even had a single case of typhoid fever, and it had escaped cholera even when the surrounding country suffered from it. Suddenly, in August, 1872, an outbreak of typhoid fever occurred, affecting a large part of the entire population. A short distance south of Lausen was a little valley, the Fürlerthal, separated from Lausen by a hill, the Stockhalden, and in this valley upon an isolated farm on June 19, a peasant who had recently been away from home, fell ill with a very severe case of typhoid fever which he had apparently contracted during his absence. In the next two months there occurred three other cases in the neighborhood, — a girl, and the son and the wife of the peasant.

No one in Lausen knew anything of these cases in the remote and lonely valley, when suddenly, on August 7, ten cases of typhoid fever appeared in Lausen, and by the end of nine days, fifty-seven cases. The number rose in the first four weeks to more than one hundred, and by the end of the epidemic in October to about one hundred and thirty, or seventeen per cent. of the population. Besides these, fourteen children who had spent their summer vacation in Lausen came down with the disease in Basel. The fever was distributed quite evenly throughout the town, with the exception of certain houses which derived their water from their own wells and not from the public water supply. Attention was thus fixed upon the latter which was obtained from a well at the foot of the Stockhalden hill on the Lausen side. The well was walled up, covered, and apparently protected, and from it the water was conducted to the village, where it was distributed by several public fountains. Only six

houses used their own wells, and in them there was not a single case of typhoid fever, while in almost all the other houses of the village, which depended upon the public supply, cases of the disease existed. Attention was directed to the water supply as the source of the typhoid poison, very largely because no other source could well be imagined. A distribution of the disease from the farm through the air was hardly conceivable because houses in the Fürlerthal, although lying upon the same plateau and naturally more accessible through the atmosphere, remained free from the disease, which fact seemed to prove that the infected farmhouse could not have communicated the disease to Lausen either through the ground-water or through the air.

THE FÜRLER BROOK AND THE LAUSEN WELL.

In order, however, to clinch the evidence that the well had been infected, it became desirable to show some source from which an infection, so unusual and remarkable, could have come, and precisely how it happened. There had long been a belief that the Lausen well was fed by and had a subterranean connection with a brook (the Fürler brook) in the neighboring Fürlerthal; and since this brook ran near the peasant's house and was known to have been freely polluted by the excreta of the typhoid-fever patients, absolute proofs of the connection between the well of Lausen and the Fürler brook could not fail to be highly suggestive and important. Fortunately such proofs were not far to seek. Some ten years before, observations had been made which had showed an intimate connection between the brook and the well. At that time without any known reason, there had suddenly appeared near the brook in the Fürler valley below the hamlet, a hole about eight feet deep and three feet in diameter, at the bottom of which a considerable quantity of clear water was flowing. As an experiment, the water of the little Fürler brook was at that time turned into this hole, with the result that it all flowed away underground and disappeared. An hour or two later the public fountains of Lausen which, on account of the dry weather prevailing at the time, were barely running began flowing abundantly. The water from them which was at first turbid, later became clear; and they continued to flow freely until the Fürler brook was returned to its original bed and the hole was filled up. But every year afterwards whenever the meadows below the site of the hole were irrigated or overflowed by the waters of the brook,

the Lausen fountains soon began to flow more freely. In the epidemic year (1872) the meadows had been overflowed as usual from the middle to the end of July, which was the very time when the brook had been infected by the excrements of the typhoid patients. The water supply of Lausen had increased as usual, had been turbid at the beginning and had had a disagreeable taste. About three weeks after the beginning of the irrigation of the Fürler meadows fever broke out, suddenly and violently, in Lausen.

EXPERIMENTAL DEMONSTRATION OF CONNECTION BETWEEN THE FÜRLER BROOK AND THE LAUSEN WELL.

In order to make matters, if possible, more certain, the following experiments were made, but unfortunately not until the end of August when the water of the Lausen supply had again become clear. The hole which had appeared ten years earlier, and had afterwards been filled up, was dug out and the little brook was once more led into it. Three hours later the Lausen fountains were yielding double their usual volume. A quantity of brine containing about eighteen hundred pounds of common salt was now poured into the brook as it entered the hole, whereupon there appeared very soon in the Lausen water, first a small, later a considerable, and finally a very strong, reaction for chlorine, while the total solids increased to an amount three times as great as before the brine was added. In another experiment, five thousand pounds of flour (*Mehl*), finely ground, were likewise added to the brook as it disappeared in the hole; but this time there was no increase of the total solids, nor were any starch-grains detected in the Lausen water. It was naturally concluded from these experiments that while the water of the brook undoubtedly passed through to Lausen and carried with it salts in solution, it also underwent a filtration which forbade the passage of suspended matters as large as starch-grains.

Unfortunately, this was before pure cultures of bacteria were known and no experiments were made with suspended matters as small as bacteria. Dr. Hägler, from whose report the foregoing facts are taken, was careful, however, to state that "it is not denied that small organized particles, such as typhoid fever germs, may nevertheless have been able to find a passage." As a matter of fact, Dr. Hägler's minute account does to-day give us some indication that such germs might easily have passed from the brook to Lausen, for the turbidity of which he repeatedly speaks is evidence of the passage

of particles probably as small as, and possibly smaller than, the germs of typhoid fever. (*Typhus und Trinkwasser*, *Vierteljahrschrift für öffentliche Gesundheitspflege*, *VI*, *154*; *also Sixth Report*, *Rivers Pollution Commissioners of 1868*. *London*, *1874*.)

EFFECT OF THE LAUSEN EPIDEMIC UPON CURRENT THEORIES.

This epidemic formed the subject of lengthy debates and discussions between the defenders of the "Trinkwasser" theory, the "Grundwasser" theory, and the "Pythogenic" theory. The biologists naturally took sides with the first of these; the second was upheld by Pettenkofer and his powerful school; and the third by the followers of Murchison, the original exponent of the theory that filth is in itself somehow capable of generating specific diseases. This last theory had already begun to decline, and after the publication of Dr. William Budd's famous work on typhoid fever in 1873, found few supporters.

The "Ground-water" theory of typhoid fever was based upon the fact that in some cases typhoid fever has undoubtedly been more abundant when the level of the ground water is low and less frequent when that level is high. It was fortunate in its principal exponent and defender, Professor Pettenkofer, of Munich, — who has just expired only three days ago, almost exactly with the century in which he was so prominent a figure; but it was based upon an assumption which though often true is not invariably true, while the facts for which it accounted were susceptible of other explanations far more intelligible and satisfactory. Moreover, it utterly failed to account for outbreaks like that in Lausen. The latter, on the other hand, was perfectly simple on the assumption that the germs of disease had passed from the patients in the valley to the water-takers in Lausen; while the fact that they had for years been drinking from a polluted but uninfected brook completely disproved the pythogenic theory. In brief, when some years later the noise of the controversy had died away, it was gradually perceived that the opponents of the drinking-water theory had been completely routed, and that this theory and its analogue, the germ-theory of disease, had won a great and decisive victory.

INVESTIGATIONS BY THE RIVERS-POLLUTION COMMISSION OF 1868.

Meantime English sanitarians had not been idle. The pollution of the rivers of England by sewage and manufacturing wastes had

become an evil so serious that a Royal Commission was appointed in 1868 to investigate and report upon the subject, and their results constitute one of the most important contributions to the progress of water-supply sanitation within the century. The Reports of the Rivers Pollution Commission are a great mine of sanitary information and a magnificent monument to sanitary research. Among many other subjects, the commissioners were, fortunately, especially instructed to investigate the whole question of the water supply of England and Scotland, and we owe to their studies the first proofs that the self-purification of streams is incomplete and untrustworthy, and the first sound evidence and recognition of the sanitary value of filtration in the purification of polluted waters. I have already touched briefly upon the former topic, and need not deal with it further here. The latter, however, requires more extended treatment, as this period marks the scientific beginning of those remedial measures for polluted water supplies with which we are so much concerned at the end of the century.

THE BEGINNINGS OF WATER-SUPPLY PURIFICATION BY MEANS OF FILTRATION THROUGH SAND.

One of the earliest modern movements, if not the earliest, looking toward the purification of a public water supply, occurred in London in 1828, when a Royal Commission discussed the improvement of the quality of the water supply of London by means of filtration. The water companies, stimulated by the Report of the Commission, began to experiment and soon "found that when the water was allowed to filter downwards through a porous bed of sand, held up in its place by underlying layers of coarse gravel, the dirt did not penetrate into its mass but was stopped at the upper surface, so that the whole cleaning operation necessary was to scrape this surface off to a slight thickness, and when it had become too much diminished, to put fresh sand on. The plan of filtration thus matured was at once carried into practice. The first large filter of one acre area was set to work by the Chelsea Company in 1829. It was found to work well, and the principle has since been universally adopted." (*Report of the Royal Commissioners of 1866–1867 on Water Supply, p. xliii. London, 1869.*)

By an act of Parliament (15 and 16 Victoria, Cap. 84) which received the royal assent July 1, 1852, it was ordered that all water for domestic use in the metropolis should, from and after Decem-

ber 31, 1855, be "effectually filtered," unless it were pumped from wells.

There is no lack of evidence, however, that the filtration was very imperfect not only earlier, in 1850, but also in 1854 and even as late as 1874. Dr. Hassall, after studying microscopically the London water supply, writes in 1850: "The importance of filtration it is almost impossible to overestimate. . . . The method of filtration, to be successful even to a limited extent, must be very different from that pursued by the Metropolitan Companies; for . . . the waters which they supply, after having undergone the process as conducted by them, still contain much solid organic matter, living, dead, and decomposing, and often of considerable size. . . ." (*A. H. Hassall, M.D., A Microscopic Examination of the Water Supplied to the Inhabitants of London. London, 1850.*)

During the cholera epidemic of 1854, the water supply of London was carefully examined, and it is recorded that "the Lambeth water is comparatively a pure water, clear and bright. . . . This water is filtered, but the Southwark and Vauxhall water is not filtered. . . . The greatest amount of foreign matter existed in the water supplied by the Chelsea Company. . . . Next to the Chelsea water was found to be that of the Southwark and Vauxhall Company. . . ." (*Dr. Sutherland's Report, pp. 43, 44, l. c.*)

In 1866 the constitution of the Thames Conservancy Board was altered and its powers enlarged by an act (29 and 30 Victoria, Cap. 89) which made two important provisions for ensuring the purity of the water, namely: first, the surface of the water of the river was to be effectually scavenged; second, the admission of sewage or any other offensive or injurious matter into the Thames, or into any tributary of it within three miles of its junction with the Thames, was declared illegal and subject to heavy penalties. In 1868 a similar act was passed for the better conservation of the purity of the river Lee, another of the sources of water supply for London.

The processes of filtration appear to have been gradually improved, though by no means perfected, after 1854, and the cholera in London in 1866 served to show in the most striking manner the very great sanitary value of even shallow sand-filters. Unfortunately, the obvious lesson from this experience was not universally accepted probably because of the confusion of thought and opinion caused by the "pythogenic" theory, the "ground-water" theory, and the "predisposition" theory, all of these contending with

the "drinking-water" theory and the "germ" theory, then just beginning to be seriously considered. It is very interesting and instructive to observe that even the Rivers Pollution Commissioners, although they themselves show that both actual experience and chemical analyses prove in the clearest manner the great sanitary value of filtration in the purification of water supplies; and although in the body of their Sixth Report (1874) they draw from these facts the natural and logical conclusions; have, nevertheless, placed at the end of that section of their Report dealing with the subject a remarkable paragraph virtually rejecting their own conclusions and warning their readers against dependence on filtration as a sanitary safeguard. Moreover, their final "Conclusions and Recommendations," briefly summarized at the end of the volume, are so plainly unfavorable to filtration as to excite surprise to any one who has carefully read the evidence of its value which they themselves give in the body of their Report. The modern student of the subject will find it difficult to resist the suspicion that these final paragraphs were inspired and appended in consequence of a careful consideration by the commissioners of the Lausen epidemic in 1872. There is internal evidence of the probability of this hypothesis in the final paragraphs themselves and in the date of the Report, in addition to the well-known fact that the Lausen epidemic made everywhere a profound impression and was widely and even hotly discussed. One example of this peculiar attitude of the commissioners towards filtration may be cited: —

"The improvement of the quality of drinking-water by filtration has scarcely received so much attention as it deserves. . . . Whenever towns have the misfortune to be supplied with water from rivers polluted by sewage, efficient filtration should always be stringently insisted on. . . . We have already explained the frightful results which occurred in the east of London in the cholera epidemic of 1866 from probably not more than a single hour's suspension of filtration. . . ." (*Sixth Report, pp. 216, 218.*)

Per contra: "We desire it to be distinctly understood that although this purification . . . may reasonably be considered on theoretical grounds to be some safeguard against the propagation of epidemic diseases, there is not in the form of actual experience a tittle of trustworthy evidence to support such a view. On the contrary, the investigation of the epidemic of typhoid fever at Lausen, in Switzerland, proves that even very efficient filtration does not

prevent the propagation of that fever by water. . . ." (*Sixth Report, p. 221.*)

INFLUENCE OF BACTERIOLOGY UPON THE THEORY OF FILTRATION.

In brief, the conclusions of the Rivers Pollution Commissioners bore heavily against the sanitary efficiency of filtration, and served to strengthen the doubts of its value naturally raised by the phenomena of the Lausen epidemic. Facts tending to show the efficiency of filtration, such as those observed in the cholera epidemics of 1854 and 1856, were overlooked or disregarded and very little further progress was made in its study until the introduction of the novel methods of bacteriology rendered it possible and easy for Prof. P. F. Frankland to show, in 1886, a very high efficiency of the London filters in removing microbes from the waters of the Thames and the Lee. Similar results were obtained in America soon after for the Merrimac River at the Lawrence Experiment Station of the Massachusetts State Board of Health, and these were succeeded by an experiment upon the large scale in the installation of the municipal filter for the city of Lawrence, which was in turn followed by the reduction of an excessive death-rate from typhoid fever to one on a level corresponding to that of neighboring cities supplied with pure water.

These various results and the painful experience of Hamburg with cholera in 1892 resulting from the use of unfiltered water, while its next-door neighbor, Altona, enjoyed almost complete exemption, — though using water from the same river at a lower point and even more polluted, — simply because it first subjected the water to slow filtration; the favorable experiences with filtration of Berlin, Warsaw, and many other cities which have adopted filters of the English type; the remarkable experience of London itself, which since 1866 has continued to use largely for domestic purposes the well-filtered water of the rivers Thames and Lee, and yet has maintained a very low death-rate from infectious diseases; the lack of any fresh epidemic like that at Lausen to throw doubt on the efficiency of the process when wisely conducted; the general triumph of the germ-theory of infectious disease; and the rise of bacteriology, — all these and other favorable circumstances have naturally created the firm conviction that in filtration we have the best method yet discovered for purifying polluted waters so that they may be not only agreeable to look at but also safe and wholesome for drinking.

EXPERIMENTAL STUDIES ON THE THEORY AND PRACTICE OF FILTRATION.

The art of filtration has accordingly received in the last years of the century a great amount of attention. Its theory and practice have been carefully studied, — perhaps more carefully at the Lawrence Experiment Station of the Massachusetts State Board of Health than anywhere else, — and its applicability to various kinds of water under various conditions has received elaborate and extended investigation, especially at Louisville, Ky., and Cincinnati, Ohio, under the direction of Mr. George W. Fuller, and at Pittsburgh, Pa., by Mr. Allen Hazen. Under the advice and direction of Mr. Hazen, the city of Albany, N. Y., in 1899 constructed a municipal filter of the most modern type for the purification of the polluted Hudson River which, unfiltered, had long been at once the source of water supply and the cause of an excess of typhoid fever in Albany. This filter has already demonstrated its sanitary efficiency and will probably stand in the future as a representative example of the best practical achievement of the century in the purification of a polluted water supply by slow sand filtration.

PROTECTION OF THE PURITY OF WATER SUPPLIES AGAINST POLLUTION AT THEIR SOURCES.

Meantime we have been taught by other epidemics that a water supply undergoing alterations at its source and exposed to pollution by filthy workmen may be the effective vehicle of disease, — as happened in Caterham, England, in 1879, when the excretions of a single sick laborer, working in a new supply well in the chalk, apparently caused an extensive outbreak of typhoid fever among the users of the water; and we have learned by painful experience that excrements of typhoid-fever patients thrown upon a watershed may find their way into reservoirs or rivers and cause great epidemics like that at Plymouth, Pa., in 1885, and that at Lowell and Lawrence, Mass., in 1890–91.

PRESENT STATE OF THE SUBJECT.

The nineteeth century has thus witnessed the gradual rise of modern water-supply sanitation and considerable progress in its various branches. It is now agreed on all sides that impure water may be not merely a predisposing cause, but the actual vehicle, of infectious diseases such as Asiatic cholera and typhoid fever. The

"ground-water" theory and the "pythogenic" theory of typhoid fever have disappeared and the "germ" theory is the only one recognized to-day. One phase of this, now everywhere accepted, is the "drinking-water" theory which, under the head of "*Typhus und Trinkwasser*," was so much debated between 1865 and 1885.

Filtration through sand, proposed in 1828, begun in London in 1829, and required by law for river-waters in London after 1855, was at first slowly and empirically improved as an art, though its existence and sanitary value were repeatedly justified, especially in the cholera epidemic of 1866. It nevertheless passed under a cloud for a time, chiefly because of the phenomena of the Lausen epidemic of 1872, which seemed to show that even the most extensive filtration of an infected water supply was insufficient to remove the poison of the disease, and was only restored to its proper place in the confidence of experts after the lapse of time, the gradual accumulation of evidence in its favor, the powerful support of bacteriology, and especially after fresh and indubitable demonstrations of its efficiency and value, such as those afforded by the long experience of London, that of Altona in 1892, and that of Lawrence in 1893, etc.

The nineteenth century has also witnessed great progress in the general recognition of the absolute necessity of carefully protected watersheds, not only for the collection of surface waters which are to be used without filtration but also for those — such as the water of the Thames — which are to be both settled and filtered before their consumption. It has learned to recognize the fact that the so-called purification of polluted waters by "running" in rivers, and even by "storage" in small reservoirs, is often incomplete and untrustworthy, and recognition of this fact has led to great and enormously expensive undertakings such as the Metropolitan Water Works of Massachusetts and the Sanitary Drainage Canal of Chicago, both designed to secure not merely more abundant, but also purer, water supplies.

DISCUSSION.

Mr. George F. Chace.* It goes without saying, Mr. President, that we have all been very much interested in what Professor Sedgwick has said, and we are very much indebted to him. When he was speaking of lead pipes I could not help thinking of an old surgical story that I read some years ago. It seems a man had had an iron rod driven into his body somewhere, and when the surgeon

*Superintendent, Taunton Water Works.

was called to see what could be done for him, after he made his examination, he said: "If that iron is taken out of your body, in the position in which it is, you would bleed to death; if it stays there mortification will ensue, and that will kill you. Science has its limits and you may take your choice of deaths."

Now, I don't suppose there is a water-works man here who would not from a mechanical point of view prefer to use lead service pipes. It is a great deal less trouble in delivering water to consumers. There are a great many lead house pipes in some cities, and they find comparatively little difficulty with the water.

When our water works were built in Taunton, I think in almost every house there were iron service pipes, and these have continued to be used up to the present time almost exclusively. Our consumers got along very well up to 1894, when the Lakeville supply was put in. And the reason seemed to be, that the water which was used up to that time was not very pure in some respects. It had a considerable sediment, which formed a coating on the inside of the pipes, and which prevented very much corrosion; and unless that coating was disturbed, the service was very fair. But ever since 1894 I have been more or less abused by people who have complained of having rusty water in their houses and who have tried to lay it to the water department; and time and time again I have had occasion to disconnect the house pipe from the service pipe where it entered the cellar and show consumers that the water was clean from the main to the house, and that the trouble was in their own pipes; and I have told them again and again that so long as they continued to use plain iron pipes they would have rusty water, and that the cleaner and purer the water, the more it would rust the pipe. The remedy is to use some other kind of pipe, like tin-lined pipe, but that costs more. Much of the difficulty in remedying these sanitary troubles is that there are so many people in this world whose god is their pocketbook. If we are willing to pay the price, we can get along and lead rather healthy lives; but it will cost us something.

THE CAUSES OF RAINFALL.

BY PROF. W. M. DAVIS, HARVARD COLLEGE, CAMBRIDGE, MASS.

[*An Informal Talk at the Meeting of February 13, 1901.*]

Mr. President and Gentlemen, — A study of the causes of rainfall may have a certain interest to men engaged in water-works problems, but the study is not one which can result in modifying rainfall by anything that we can do. One of the chief results in the study of this problem is the discovery that we must take rainfall just as it comes; we cannot change it. We may utilize what comes, we may wish that more or less would come at times, but the artificial production of rainfall is believed to be practically impossible; and so also is the increase or reduction of the amount that falls. In illustration of this I will run briefly over the general physical principles involved in the occurrence of rainfall in the natural way.

In the first place, the supply of water vapor to the atmosphere comes primarily from the ocean. But it has been found by comparing the total rainfall and the total run-off of rivers that a very considerable part of our rainfall is supplied by water vapor from the lands, so that every drop falls two or three times. The vapor from the ocean falling on the land does not run directly back by streams to the ocean again, as the general statement would imply. A drop will probably fall two or three times between its departure from the ocean and its return there. The direct supply of vapor for rainfall is, therefore, not always the ocean. The vapor may come from rain that has lately fallen on the land, as a rule to windward; the rain passes off as vapor into the atmosphere and falls again, and may even fall a third time before it gets back to the ocean.

Regarding the processes of getting water out of the air, there are certain terms ordinarily used that imply a wrong physical view. For example, it is said that the air on being cooled reaches saturation. Now the word "saturation" means literally that air saturated with vapor might be compared with a saturated solution of salt in water, for example; but the analogy is a very false one, because there is no such relation between water vapor and air as there is between salt

and the water in which it is dissolved. Water will hold a certain quantity of salt at a certain temperature. It is said, when that amount is fully supplied, that the water is saturated with salt. But when the air contains as much vapor as can exist, the quantity of vapor is not determined by the mere presence of the air. The water vapor is not in any proper sense dissolved in the air; it is simply mixed with it. The air, being in much greater quantity than the water vapor which it contains, determines the temperature at which the water vapor must exist, and then the temperature given to the vapor by the presence of a much greater amount of air will determine how much vapor there may be. Indeed, water vapor can exist alone to the same quantity as in the presence of air; that is to say, water can be evaporated into a vacuum, and at a temperature of sixty degrees there might be just as much water vapor there alone, without any air to hold it, as if air were there at the same temperature. It is, therefore, the temperature of the air, and not the presence of the air, that controls the amount of vapor that may form. Again, the illustration sometimes offered of squeezing a sponge and letting the water drop from it, implying that we get rain from the air in that way, is entirely false. There is no such process at all. It is not by squeezing, or compressing the air, but, as a rule, by expanding it, that rain is caused to fall.

The vapor, being formed and mixed or diffused in the air, is carried about by the wind. Condensation will then result whenever the cooling of the air is carried to such a point that all the water vapor cannot exist as vapor; and as the cooling is continued, more and more of the vapor will be forced to condense. If the condensation is active enough, some of the condensed vapor will fall as rain or snow. So the whole process of rainfall depends on some process that will cool the air, and the vapor with it, sufficiently to provoke condensation.

The processes of cooling are various. If close to the earth's surface, the cooling of the ground by radiation at night may cause sufficient cooling of the air to condense some of the vapor from it, but the quantity thus condensed is small. Indeed, recent studies of the formation of dew have shown that a considerable part of it is not derived from the air, but is condensed from vapor rising out of the ground, or from vegetation. All sources, however, doubtless contribute to the production of dew. The amount of water thus produced is small, and not to be compared in this climate with the

abundant supply that we get from the sky, which is the result of active and abundant changes of temperature of the free air.

There are various ways in which these changes can be produced. One of them would be a poleward movement (northward in this hemisphere and southward in the other), because as a rule the temperature of the air will decrease as it moves to a higher latitude. This cooling does not, however, take place because the moving air finds colder air in its new position and is thus cooled by contact or mixture, for, as the warm air comes to its new position, the air which has been there before goes away. As the warm air goes to a higher latitude it takes a position with respect to sunshine that allows it to cool by radiation, and cooling in this way may go on sufficiently to provoke condensation, beginning, of course, by making the air cloudy, and continuing by making the clouds drip in the form of snowflakes or raindrops. But it is not ordinarily the case that cooling by poleward movement alone suffices. This process is usually supplemented by some peculiar commotion in the atmosphere. Under the general conditions of atmospheric circulation the movements of the air are not from equator towards pole, but are obliquely poleward and eastward. One might at first think that the convectional interchange between equator and pole would cause abundant movements along the meridian towards the pole, and that rainfalls thus determined would be predominant; but the rotation of the earth prevents meridional circulation and requires that the winds shall flow obliquely. On account of this motion being prevailingly oblique, the rate of cooling thus produced is very small. Theoretically this is an available process for the production of rain; practically the conditions are seldom provided to enable it to produce much rainfall.

The ascent of the air from a lower to a higher level is a most effective cause of cooling and vapor condensation wherever it can be produced. For instance, winds blowing against a mountain range must climb over the range, and in doing so they rise to a much higher level, expand and cool. This very often produces a sufficient cooling to provoke the formation of clouds and rain. It is worth noticing that the older forms of statement regarding this change are erroneous. A former way of stating it was that the air, rising to colder regions of the atmosphere, was cooled, as if by conduction to its colder surroundings, and so became cloudy. It is true that the air may rise to an altitude where the surrounding temperatures

are less than its own, but the reason that the rising air is cooled is not because it enters a region where the surrounding air is cold, but because in rising it expands, and in expanding it is mechanically cooled; it cools itself. This is a much more effective process of cooling than the mere contact of another body of cold air, for the latter process would be effective only close to the surface of contact, while expansion necessarily operates throughout the whole mass, absolutely and intimately. The ascent of air over lofty mountains is for this reason nearly always accompanied by clouds and rainfall; this must be so unless the air in beginning the ascent is extremely dry, so that in spite of an ascent of a number of thousand feet it still would not be cooled enough to become cloudy.

Cooling by ascent would be an effective process, as thus far described, only in mountain regions. For example, the westerly winds blowing from the Pacific Ocean against the coast mountains of British Columbia, or from the Atlantic against the coast mountains of Scotland and of Norway, would be provoked to cloudiness or perhaps to rainfall by this process. But rain is not limited to those regions only. Rain falls also in relatively low countries, and in such regions the rainfall is, I believe, in most cases, connected with an ascent of air not due to climbing over mountain ranges, but to climbing up in one of these great whirling bodies of air whose lower members are so well shown on the weather maps, and to whose general mass the name of "cyclonic storm" is now given. In such a commotion of the atmosphere there is oftentimes a rather active ascent of the lower air to higher levels. Not only so, but the inflowing air currents generally include an inflow which comes from the equatorial side, and this, flowing north, will cool according to the conditions which have been already stated, as well as because of the ascent. The combination of these two processes is all the more effective; it seems to be the chief cause of the rainfall that we receive. The winds, coming from southerly and moister regions towards our northern position, where they must cool, and at the same time climbing, as it were, many thousands of feet in the areas of low pressure, must become cloudy and rainy. That it is not merely the climbing around the cyclonic centers, but that the poleward movement is also a contributive cause, is shown by the general absence of rain in the northerly or northwesterly indraft of the same storm. The northwesterly winds come from a continental interior and are comparatively cold and dry; they warm as they advance,

and thus increase their capacity for vapor instead of diminishing it, while the southerly winds cool as they come towards us and hence are prevailingly cloudy and rainy.

In winter time the process thus sketched is aided still further by the contrast between the warm ocean and the cold continent. The winds that blow from the Gulf of Mexico or from the adjacent Atlantic up the Mississippi Valley or into this part of the country will, as they pass from the ocean over the land, move from warm waters to cold lands, and, so far as the temperature of the air is dependent on the interchange or radiation between the earth's surface and the air itself, this change of position tends to cause a cooling. Hence in winter the cooling caused by the poleward movement of our southerly winds around a low pressure center and the climbing of the winds around the center of low pressure is supplemented by the movement of the wind from a warm water region to a cold land region. You may notice that in the summer time an area of low pressure will generally have a less extent of cloud than in winter time, probably because at that time the winds are blowing from the water over the warm lands, and the third process of cooling just mentioned is not then operative: but also because summer storms are weaker than winter storms.

Finally, there is in the summer time an additional method of making rainfall, and that is in the sudden overturnings of the atmosphere that we see in thunder storms. In summer a very considerable share of our rainfall comes from thunder storms. This is especially true in the Mississippi Valley, where a greater rainfall occurs in the summer months, and where the summer rainfall is due in large part to thunder storms. Thunder storms seem to be due to an excessive amount of heat and moisture in the lower air, which thus becomes unstable and overturns, cooler air taking its place. The overturning is in many cases so active and the ascent so great that the ascending air becomes greatly cooled, enormous mountain-high clouds are formed, and drenching rains fall from them. The reason that the rain is as a rule of greater quantity and of greater rapidity of fall in thunder storms than in winter storms is this: In a winter storm rain or snow is condensed from the atmosphere at a relatively low temperature. In summer thunder storms the rain is condensed from the atmosphere at a decidedly high temperature, for thunder storms characterize the hottest weather we have. Now the rate of decrease of capacity for vapor in the atmosphere is not a regular

one. If saturated air is cooled from thirty degrees to twenty degrees, a certain small amount of vapor is condensed from it. If it is cooled from sixty degrees to fifty degrees a decidedly greater amount of vapor is condensed. If it is cooled from ninety degrees to eighty degrees a still greater condensation occurs than at lower temperatures. That is, the rate of decrease in capacity of the atmosphere for vapor is not constant, but is much more rapid at high temperatures than at low temperatures. It is for that reason that the same amount of disturbance in the summer gives us a heavy rain, for the cooling then will take place at high temperatures, while in winter the cooling must be at low temperatures, and the vapor then condensed will be a relatively small amount.

This explanation shows why it is that the rainfall in equatorial regions is so much greater than in high latitudes. In Greenland, for example, the total precipitation is only about ten or fifteen inches, while in many places around the equator the rainfall is eighty, ninety, or one hundred inches, and in some few places four hundred or five hundred inches. That is not so much because of the greater activity of rain-making processes in the torrid zone, but because in the equatorial regions the processes work at high temperatures, and a ten-degree cooling there will exclude a much greater amount of vapor than a ten-degree cooling in polar regions, where the process must go on at low temperatures.

A few words regarding a matter which has been much talked of in the last ten years or so, namely, the value of little solid nuclei for the beginnings of condensation. Professor Aitkin, of Edinburgh, has found reason to think that condensation of vapor into liquid is difficult, unless there are some little starting points, such as ultramicroscopic dust particles. If these particles are called "dust," the word implies something altogether too coarse for what is usually present in the atmosphere. There has been objection made to this theory, because it is found that if rainfall is carefully collected, not allowing it to wash from a roof which may be dusty, but receiving it directly in a clean tank or reservoir, it is difficult to find a significant amount of dust in it. It has been thought that inasmuch as a raindrop may be the result of a coalescence of a vast number of smaller drops, every one of which ought to have its little dust nucleus, there ought to be in a large collection of raindrops a perceptible amount of sediment. This argument seems to be based on misapprehension; namely, the assumption that every raindrop is the result of the coa

lescence of a great number of minute drops. Consider the formation of snow. Snowdrops are of crystalline structure, and they are usually the growth from a single nucleus, not the result of the accidental coming together of various flakes. Imagine a flake begun on a single nucleus which then suffices for the rest of its growth; let it then melt, as a great deal of snow is melted, into rain; every raindrop thus formed will have but a single nucleus. Furthermore, if this be true for snowflakes, it is very likely true also for raindrops. A raindrop, then, may not be the result of the coalescence of a great many minute droplets, but of the continual condensation around a droplet which was very small at first, and which may have begun on a minute dust particle. In such case the amount of sediment to be expected from rainwater must be small, as is actually the case; and the absence of sediment cannot be used as an argument against Aitkin's theory.

Now a word with regard to the attempts to produce rain artificially. You may remember the so-called "experiment" carried on in Texas a few years ago by Dyrenforth. The peculiarity of that "experiment" was that it was no experiment at all. Dyrenforth went there with his cannon and fired away into the air, and after a time a rain came along which he claimed as his own. An experiment, as you know, involves the exclusion of all other processes than the one you are studying; Dyrenforth made no attempt whatever to exclude other processes from the origin of this rain. He did not even inquire where his rain began, although everything seems to show that it began somewhere to the west and drifted along over him after he had been firing a couple of days, and passed away east of him, with little regard to his claim of proprietorship. There does not seem to be sufficient reason to believe that rain can be produced by explosions. Curiously enough, there has just begun to be current in Europe a belief that hail can be stopped by explosions. Owners of vineyards in Switzerland say that they have found that by stationing small cannons or mortars on the hills around their vineyards, and firing away actively when a storm is seen coming towards them, the storm is dissipated, and their vines are not cut to pieces by the hailstones. This is "blowing hot and cold" with the same cannon, and it seems well to be skeptical about both of these stories.

As to other artificial methods for producing rain, there were various schemes talked of at the time when the more active settlement of the sub-arid belt in the second tier of States west of the Mississippi was

going on, some fifteen years ago. You may remember that there was then a great pressure of settlers into the region where settlement was risky because of insufficient rainfall. There was much talk then in the sub-arid belt about the rainfall; I remember when out there meeting an army officer, apparently an intelligent man, who assured me that the rainfall was actually increasing on the plains. He knew this by his experience at various stations; that it was possible to raise crops now which could not have been raised earlier, and the reason for the increased rainfall was, he said, that railroad and telegraph wires had been built across the plains, and the electric conditions of the atmosphere had thus been changed. That such a supposition is absolutely gratuitous is shown by the fact that, while there was for a few years a slightly increased rainfall, there was a very disastrous decrease afterwards, — a decrease which resulted in the abandonment of many a home and ranch because the people were simply dried out. Any attempt to increase rainfall artificially seems to me to be entirely beyond our power of accomplishment.

DISCUSSION.

THE PRESIDENT. We have with us to-day Prof. W. H. Niles, of the Massachusetts Institute of Technology, from whom I know we should all be very glad to hear, and I will call on Professor Niles.

PROFESSOR NILES. *Mr. President and Gentlemen*, — I think I first owe you an apology, or, rather, an explanation. At the time of your last meeting, when my name was on your program, the grip had seized me for its own, and held me for twenty-five days, so I could not get to your meeting last month.

I have been interested in the remarks which have been made to you by Professor Davis on the causes of rainfall. As you have seen here, and as I have known for many years, he has a very remarkable ability for going through a very large subject, picking out the best of it, and putting things together in a very systematic manner, and then stating the results very clearly. He has so completely treated the causes of rainfall that I do not need to deal with the specific sources or how the atmosphere gets its water. But there is the other question as to how the water is taken from the atmosphere. This to me seems a very important question in its broadest relations to mankind. We think of ourselves as the inhabitants of the land,

but our earth is not land alone, — it has water and an atmosphere. The water and the atmosphere are great agents for the production of changes, and they are very beneficent in their work. It is true that there are certain agencies which are essentially atmospheric, but still we cannot dissociate the atmosphere from the water. They are so bound together that the discussion of the atmosphere at a meeting like this seems to me a very appropriate topic.

I suppose you find as you go into various places, as I have found, that there are people who have never studied into these subjects very much, and who have an idea that there may be great reservoirs of water somewhere below the surface, and that the water is not altogether derived from the atmosphere. You may have found, as I have, people who would not believe you if you were to tell them that all the water that comes to our reservoirs, our rivers, and our lakes has passed through the atmosphere, and that therefore we may call it meteoric water. The causes which combine to derive water from the atmosphere are varied, as Professor Davis has said, and some seem to act more forcibly in one section of the earth than they do in others. Some of these causes may be local and give us merely local storms, while others may be of more general efficiency. Sometimes the local causes perform the work, and at other times they do not have the opportunity because some of the more general changes in the atmosphere seem to overcome them, and then the rainfall depends upon the more widely extended influences. I believe it may be stated that the water which falls from the atmosphere comes partly in consequence of acts performed by the atmosphere itself. The atmosphere is a great working element. It derives its energy largely from differences of temperature, it is true, but it has other elements of power. In doing its work it has not only to absorb the water which has evaporated from the sea and from the land and transport it to other places, but it has its own special part to do in disposing of that moisture in the form of rain.

Professor Davis has spoken of the cyclonic storms. We often think of them as waves of the atmosphere, and we may regard them as associated with waves of high and low atmospheric pressures. It is when the atmosphere is thrown into these great waves or areas of relatively high and low pressures that it is capable of doing its largest amount of work, and it then gives us the largest supplies of rain. We have all of us experienced the fact that sometimes in the summer the clouds will gather and lower, and it looks as though it

would rain within an hour or two. The clouds sometimes continue for a long time, then gradually melt away, and no rain falls. The people in the country often say, "That was a dry storm," and that is pretty nearly true. These phenomena will sometimes be repeated a number of times, and then the people will make use of that old expression, "All signs fail in dry weather." There are whole seasons when all the conditions frequently indicate rain and yet rain does not come. How does it then happen that during some other year little clouds will come up scarcely threatening rain, when suddenly down it pours, so that people say, "It does n't take much to make it rain this year. Last year we could n't get any rain out of the atmosphere. The conditions did not seem to be right."

Now, this is explained very easily by these broad general conditions of the working power of the atmosphere. If the atmosphere has been set at work in great waves, rising in high pressures and descending in low pressures, then we may have an active atmosphere doing a large amount of work and yielding a considerable quantity of rain. Sometimes the air is calm day after day and there seems to be little change in progress; it is then that we do not get the results we want in a supply of rain. At other times there are great changes and much rain. I believe that the advantages which we receive from frequent rains and also from pure air depend very largely upon an agitated atmosphere. Professor Davis has expressed the same idea; namely, that the atmosphere must be set in motion. When we have storm following storm, and when we have clear weather following each, we then have the atmosphere at work. It not only transports the aqueous vapor from the sea, but it also promotes those upward currents, which are the efficient causes of precipitation. We sometimes hear people talk about leveling the areas of human action so that each man shall have the same wages that every other man has. They seem to think that is the great panacea for all the evils in society, to have all distinctions removed. But nature does not work in that way; she raises the pressure of the atmosphere in one place and reduces it in another, and it is these differentiations which give us some of the best results which come from an atmosphere yielding copious and frequent supplies of rain.

We are then living under an atmosphere which has movements that are too extended, too energetic, and too capricious for us to control. The floods threaten us with dangers, and if the rain is withheld we suffer. How may the evil be averted and the good be

retained? Only by the storage of the water the atmosphere gives us. For this we must utilize our lakes and our forests, and we must have the best means for holding and supplying us with water that engineers can construct.

This is the great work, gentlemen, to which you have the honor of applying your skill and of directing your best efforts.

Mr. George F. Chace.* I should like to ask Professor Davis one question. He may have answered it already, but if he did I overlooked it. Since 1876, when our water works were built in Taunton, we have kept a record of the rainfall at the pumping station in Taunton. Ten miles and a half from Taunton, on the shores of Assowompsett Pond, we have another pumping station, at which a record of the rainfall has been kept since 1894; and the methods of collecting the rain and keeping the record are precisely the same at both places, being the methods prescribed by the United States Weather Bureau. Now, every single year the annual rainfall at Lakeville, at the pumping station, has been less than at the pumping station at Taunton. There is a water area in that vicinity, so far as I can remember roughly, of between five thousand and six thousand acres. I should like to ask the professor what relation that water area in the vicinity of the collection of the rainfall has to the amount of rainfall.

Professor Davis. Mr. President, the best way to answer this question is not in my power. The best way is to go down to Taunton and study the matter out, perhaps spend ten years on it, and get at the facts by direct observation. If observations were made not merely on the rainfall in two places, but in twenty or in two hundred, all around the pond, on it, near it, and away from it, you would find out something which would certainly be very interesting, but even then it may be that the answer to the question would not be found. Nevertheless, this would be the best way to try to find the answer. On the other hand, one can always hazard an opinion on matters of this sort, in view of general principles; but general principles, so far as I can apply them, do not at present enable us to explain any local variation of rainfall in distances of three or four, or of five or ten miles, in a country so generally even and low as southeastern Massachusetts. What we should expect to cause rainfall there is not this hill or that valley, or this plain, field, or lake. None of those small local features can be shown to have power to effect those large movements

* Superintendent, Taunton Water Works.

of the atmosphere on which rainfall seems to depend. In order to get some understanding of the causes of rainfall, we are driven to the large movements of the atmosphere, and such movements do not seem to be produced by small local causes.

The rain clouds that pass from west to east or from southwest to northeast across our State pay very little attention indeed to small matters of topography. The records taken some years ago show that the clouds take no account at all of small matters in the way of giving more or less rainfall. Some fifteen years ago a small organization, known as the New England Meteorological Society, which some of the members present may recall, undertook the special study of thunder storms; we had something over two hundred volunteer observers, scattered all over southern New England. They reported on a systematic plan the time of beginning of the rainfall, the time it ended, the first thunder, loudest thunder, last thunder, the direction of the wind, changes of temperature, and so on. Now, one of the results of that study was the discovery that our thunder storms, as they swept across the country, did not, as far as we could tell with records of a considerable degree of detail, pay any attention to hill or valley, river, pond, or anything of the sort. We very frequently hear it said, "Thunder storms don't often come here; they go south along that valley, or north along that valley," but we found no proof of such behavior from our records. In one particular case, the storm was found entering New England from New York at about eight o'clock in the morning. It came directly across the Hudson River valley, eastward right upon the Berkshire Hills, about where Connecticut and Massachusetts join, across those hills, straight across the depression of the Connecticut valley, over the central highlands, right on across the southeastern part of the State, across Cape Cod Bay and over Cape Cod. It did not turn to the right nor to the left, it did not hurry, it did not slacken, but went on increasing in strength as the day advanced, and giving a brief but abundant rainfall as it passed. It did not seem to care in the least for any local conditions.

Therefore, with regard to this question of the difference in rainfall between Taunton and the lake, general principles do not offer any answer whatever, because all the general principles seem to refer to the large processes that are at work aloft in the air, and not to the small processes down close to the ground. But I wish very much that local studies might be taken up, and it does not seem to

me there can be any better place for them to be studied than by such an association as this, which of course must keep a number of records at stations all about, and might add to those records by multiplying them by ten or twenty. I should like very much indeed to see the results that might then be reached.

THE EFFECT OF WATER METERS ON WATER CONSUMPTION IN THE LARGER CITIES OF THE UNITED STATES.

BY GEORGE I. BAILEY, SUPERINTENDENT BUREAU OF WATER, ALBANY, N. Y.

[*Reprinted from Engineering News of April 18, 1901.*]*

Conditions arising in the operation of the water works of the city of Albany made it desirable for its officers to have information concerning the water supply of other cities.

The conditions were, an enormously increased consumption of water during the winter, almost an even rate of consumption for each hour of the twenty-four, and an insufficient pressure in high portions of the city, all of which created an urgent demand for furnishing greater quantities of water, which meant a general addition to our plant, or else methods for restricting waste.

The general conditions are not new, and as they either have occurred or will occur in almost every city, they are assumed to be of interest to water-works officials. All of these conditions sum up in the question, whether it is cheaper and better for water takers to waste water or not to waste it. It is an easy matter to give reliable estimates of cost for increasing the plant, and for furnishing and placing water meters. There is a lack of information as to how well water meters will control the supply, their life, their operating cost, and their effect upon the water taker's pocketbook. Although there is an abundance of evidence as to what has occurred in special cases and locations, we know of no general summary.

For our information we wrote to every city in the United States having a population of 25 000 people or over by the census of 1900. We received replies from 136 of the 159 cities. Available information on quantity of water furnished daily was given by 134 cities, having an aggregate population of 17 650 000. Available information on receipts from water was given by 102 cities, having a total

* This paper deals with a subject of so great importance to all water-works managers and contains so much valuable information that the editor has no apology to offer for reprinting it, although it was not presented to this Association.

population of 15 814 000. In each case the population represents more than twenty per cent. of the total population of the United States. The locations of the cities are widespread, and therefore the averages are representative. The cities which refused information were generally those whose water supply was controlled by private companies.

We find the average per capita consumption in these American cities to be 137 gallons. The effect of placing water meters is as follows: —

Taps Metered.	Consumption — Daily, per Capita, Gallons.	Consumption — Per Cent. of Average.
Less than 10 per cent	153	112
10 to 25 per cent	110	80
25 to 50 per cent	104	76
More than 50 per cent	62	45

In cities where the number of consumers was not given, we assumed that the total population was supplied. We understand that it is rare for a city to supply all its people with water, and to offset this overestimate we have taken into account that most cities have at least a partial supply received from pumps, and that the universal rule is to credit the full quantity of water calculated on plunger displacement without making any allowance for slip or leakage of pumps. The gaging of the Croton Aqueduct made by Mr. John R. Freeman, for the comptroller of the city of New York, shows an overstatement of quantity delivered by gravity through that aqueduct, and this overstatement we believe applies approximately to all such supplies. We believe, therefore, the overestimate of population is equalized by the overstatement of quantity supplied.

Where the total number of taps was not given we assumed one tap to six persons. These assumptions and some misunderstanding of questions by different officials may make slight differences, but the numbers used are so large that they would not materially affect the results.

In all cases cities were asked to state the number of consumers. There is a decided difference of opinion among water-works officials as to what constitutes a consumer. In the Northeastern and Middle States a consumer is understood to be an individual. In most of the other cities a consumer is considered a collective number of individuals, either a family or colony, supplied from a single tap. As

TABLE I. — WATER CONSUMPTION, USE OF METERS, AND I
LARGEST CITIES OF THE

(Compiled from Special Official Reports by George I. Bailey,

Rank in Population.	CITIES.	POPULATION.		CONSU (Gallons
		By Census of 1900.	Supplied.	Total.
87.	Akron, Ohio	42 728	20 000	.....
40.	Albany, N. Y.	94 151	95 000	18 100 0
113.	Allentown, Pa.	35 416	37 000	4 357 0
96.	Altoona, Pa.	38 975	37 900	.....
43.	Atlanta, Ga.	89 872	65 000	5 444 0
148.	Atlantic City, N. J.	27 838	28 500	.....
135.	Auburn, N. Y.	30 345	.....	4 500 0
6.	Baltimore, Md.	509 000	576 000	56 000 0
150.	Bay City, Mich.	27 628	17 000	3 000 0
124.	Bayonne, N. J.	32 722	.....	3 071 0
93.	Binghamton, N. Y.	39 647	.....	5 936 0
5.	Boston, Mass.	560 900	.....	80 000 0
54.	Bridgeport, Conn.	70 996	70 000	16 500 0
92.	Brockton, Mass.	40 063	35 000	1 165 0
8.	Buffalo, N. Y.	352 400	400 000	92 365 0
133.	Butte, Mont.	30 470	45 000	.....
41.	Cambridge, Mass.	91 886	.....	.....
52.	Camden, N. J.	75 935	50 000	14 000 0
132.	Canton, Ohio	30 667	.....	3 750 0
157.	Cedar Rapids, Ia.	25 656	.....	3 000 0
68.	Charleston, S. C.	55 807	.....	1 800 0
117.	Chelsea, Mass.	34 072	.....	3 000 0
2.	Chicago, Ill.	1 698 600	.....	323 000 0
10.	Cincinnati, Ohio	325 900	.....	39 600 0
7.	Cleveland, Ohio	381 800	420 000	66 900 0
28.	Columbus, Ohio	125 560	100 000	23 000 0
156.	Council Bluffs, Ia.	25 802	.....	2 000 0
86.	Covington, Ky.	42 938	.....	2 500 0
114.	Davenport, Ia.	35 254	20 000	3 000 0
45.	Dayton, Ohio	85 333	.....	5 300 0
25.	Denver, Col.	133 859	100 000	.....
59.	Des Moines, Ia.	62 139	.....	3 000 0
14.	Detroit, Mich.	285 700	306 055	44 800 0
107.	Dubuque, Ia.	36 297	.....	2 500 0
72.	Duluth, Minn.	52 969	15 000	4 100 0
158.	Easton, Pa.	25 238	25 000	2 000 0
112.	Elmira, N. Y.	35 672	20 000	4 500 0
73.	Erie, Pa.	52 733	.....	7 458 0
64.	Evansville, Ind.	59 007	.....	8 000 0
33.	Fall River, Mass.	104 863	104 500	3 805 0
128.	Fitchburg, Mass.	31 531	25 000	3 000 0
83.	Fort Wayne, Ind.	45 115	.....	3 500 0
151.	Fort Worth, Tex.	26 688	30 000	3 000 0
153.	Gloucester, Mass.	26 121	.....	950 0
44.	Grand Rapids, Mich	87 565	.....	13 693 0
77.	Harrisburg, Pa.	50 167	57 000	8 202 5
49.	Hartford, Conn.	79 850	80 000	8 500 0
104.	Haverhill, Mass.	37 175	38 000	.....
82.	Holyoke, Mass.	45 712	45 700	.....
21.	Indianapolis, Ind.	169 164	.....	13 400 0
159.	Jackson, Mich.	25 180	.....	.....
142.	Jacksonville, Fla.	28 429	20 000	2 136 0
17.	Jersey City, N. J.	206 433	200 000	32 020 0
111.	Johnstown, Pa.	35 936	33 000	4 750 0
137.	Joliet, Ill.	29 353	.....	3 000 0
22.	Kansas City, Mo.	163 752	.....	.....
76.	Kansas City, Kan.	51 418	.....	4 301 0
125.	Knoxville, Tenn.	32 637	23 400	2 800 0
140.	La Crosse, Wis.	28 895	29 000	5 585 0
90.	Lancaster, Pa.	41 459	.....	6 000 0
57.	Lawrence, Mass.	62 559	57 200	3 204 0
152.	Lexington, Ky.	26 369	.....	1 250 0

AND RECEIPTS FOR WATER IN OVER ONE HUNDRED OF THE F THE UNITED STATES.*

Bailey, Superintendent of the Bureau of Water, Albany, N. Y.

Consumption allons per Day).		Average Annual Receipts.		Number of Taps.	Meters in Use.	Percentage of Taps Metered.	Meters Furnished by †	Meters Set by †
Total.	Per Consumer.	Total.	Per Consumer.					
.....	200	Private.	....	4 276	400	9.35	D	D
100 000	191	$292 000	$3.07	16 500	2 030	12.30	D	B
357 000	118	61 800	1.70	.....	17	....	C	C
.....	95	68 000	1.79	8 496	225	2.64	D	D
444 000	84	133 800	2.06	9 275	8 500	91.64	C	C
.....	80	110 000	3.86	4 249	3 298	77.62	D	D
500 000	148	75 000	2.47	5 000	400	8.00	D	D
000 000	97	950 000	1.65	110 000	1 607	1.46	C	C
000 000	177	45 000	2.65	2 200	826	37.54	D	C
071 000	94	139 000	4.25	3 000	3 000	100	C	C
936 000	156	95 000	2.47	7 000	523	7.47	B	D
000 000	143	2 233 000	3.98	81 000	4 455	5.50	D	D
500 000	236	Private.	....	8 000	171	2.14	D	D
165 000	32	77 000	2.20	5 275	4 300	81.51	C	C
365 000	233	650 000	1.62	64 638	1 049	1.62	..	..
.....	100	Private.	....	5 531	341	6.17	D	D
.....	79	324 000	3.53	14 207	860	6.05	D	D
000 000	280	161 000	3.22	14 000	197	1.41	D	D
750 000	122	36 000	1.17	4 300	45	1.05	B	C
000 000	117	Private.	....	2 800	60	2.14	D	C
800 000	32	Private.	....	1 750	20	1.14	C	C
000 000	88	88 000	2.58	6 146	118	1.92	D	D
000 000	190	3 250 000	1.91	200 000	6 500	3.25	C	C
600 000	121	764 000	2.34	36 000	2 745	7.63	C	C
900 000	159	766 000	1.82	63 632	3 143	4.94	B	B
000 000	230	165 000	1.65	14 608	4 960	33.95	C	C
000 000	78	Private.	....	2 761	557	20.17	B	B
500 000	58	75 000	1.75	5 300	4 150	78.30	D	D
000 000	150	Private.	....	4 000	1 500	37.50	D	D
300 000	62	133 000	1.56	12 000	5 600	46.67	D	B
.....	300	Private.	....	23 549	282	1.19	C	C
000 000	48	Private.	....	7 499	4 289	57.19	D	C
800 000	146	465 000	1.52	55 340	5 555	10.04	D	D
500 000	69	74 000	2.04	1 980	125	6.31	C	C
100 000	273	133 000	8.87	2 795	1 261	45.11	C	C
000 000	80	.....	....	2 200	100	4.55	D	D
500 000	225	Private.	....	4 000	612	15.30	D	D
458 000	142	139 000	2.64	11 163	266	2.38	D	D
000 000	136	76 500	1.30	5 367	12	0.21	D	D
805 000	36	168 600	1.61	6 943	6 544	94.25	C	C
000 000	120	68 500	2.74	4 437	2 427	54.70	B	B
500 000	78	55 000	1.22	7 804	1 400	17.94	C	C
900 000	100	84 2[illegible]	2.81	3 209	247	7.75	D	B
950 000	36	76 000	2.91	2 817	56	1.99	D	C
893 000	156	125 946	1.44	8 901	1 193	13.40	?	B
202 500	144	115 800	2.03	12 000	4 278	35.65	B	C
500 000	106	250 000	3.12	9 351	2 550	27.27	D	D
.....	95	96 400	3.01	5 300	550	10.38	D	C
.....	..	90 042	1.97	3 610	210	5.82	C	D
100 000	79	325 000	1.92	10 046	600	5.97	D	C
.....	100	30 000	1.19	3 300	400	12.12	D	D
36 000	107	53 649	2.68	2 335	1 154	49.42	D	D
920 000	160	838 000	4.19	25 000	500	2.00	D	D
750 000	144	Private.	....	4 100	40	0.98	D	D
900 000	102	.....	....	2 500	300	1.20	C	C
.....	62	420 000	2.56	13 000	5 200	40.00	C	C
201 000	84	Private.	....	2 370	750	31.65	C	C
300 000	120	Private.	....	4 250	380	8.94	B	B
385 000	193	33 150	1.14	3 300	40	1.21	C	C
00 000	145	103 000	2.48	6 000	500	8.33	B	B
04 000	56	103 600	1.81	5 926	4 386	74.01	C	C
50 000	47	Private.	....	1 500	1 482	99.47	D	C

22.	Kansas City, Mo.	163 752	.....	.....
76.	Kansas City, Kan.	51 418	.....	4 301 0
125.	Knoxville, Tenn.	32 637	23 400	2 800 0
140.	La Crosse, Wis.	28 895	29 000	5 585 0
90.	Lancaster, Pa.	41 459	.....	6 000 0
57.	Lawrence, Mass.	62 559	57 200	3 204 0
152.	Lexington, Ky.	26 369	.....	1 250 0
91.	Lincoln, Neb.	40 169	25 000	2 000 0
36.	Los Angeles, Cal.	102 479	90 000	17 000 0
18.	Louisville, Ky.	204 731	160 000	.....
39.	Lowell, Mass.	94 969	94 000	8 000 0
55.	Lynn, Mass.	68 513	73 000	4 660 0
120.	Malden, Mass.	33 664	.....	1 700 0
65.	Manchester, N. H.	56 987	.....	3 500 0
115.	McKeesport, Pa.	34 227	.....	2 500 0
37.	Memphis, Tenn.	102 320	80 000	10 000 0
15.	Milwaukee, Wis.	285 300	300 000	24 000 0
19.	Minneapolis, Minn.	202 718	.....	18 813 0
98.	Mobile, Ala.	38 469	19 500	2 800 0
47.	Nashville, Tenn.	80 865	.....	11 300 0
16.	Newark, N. J.	246 070	255 000	24 000 0
58.	New Bedford, Mass.	62 442	55 000	6 320 0
155.	New Britain, Conn.	25 998	25 000	.....
31.	New Haven, Conn.	108 027	.....	.....
13.	New Orleans, La.	287 100	.....	13 820 0
144.	Newport, Ky.	28 301	.....	2 000 0
122.	Newton, Mass.	33 587	32 800	2 086 0
1.	New York, N. Y.	3 437 200	.....	400 000 0
80.	Norfolk, Va.	46 624	40 000	5 250 0
56.	Oakland, Cal.	66 960	80 000	12 500 0
35.	Omaha, Neb.	102 555	.....	18 000 0
145.	Oshkosh, Wis.	28 284	.....	2 500 0
149.	Passaic, N. J.	27 777	.....	2 500 0
32.	Paterson, N. J.	105 171	98 000	12 600 0
95.	Pawtucket, R. I.	39 231	80 000	6 524 0
67.	Peoria, Ill.	56 100	.....	3 500 0
3.	Philadelphia, Pa.	1 293 700	1 254 000	287 188 0
11.	Pittsburg, Pa.	321 600	234 000	54 000 0
42.	Portland, Ore.	90 426	90 000	18 000 0
20.	Providence, R. I.	175 597	187 300	10 130 0
147.	Pueblo, Col.	28 157	15 000	4 000 0
108.	Quincy, Ill.	36 252	.....	1 650 0
139.	Racine, Wis.	29 102	.....	1 360 0
50.	Reading, Pa.	78 961	77 900	7 180 0
46.	Richmond, Va.	85 050	.....	10 048 0
24.	Rochester, N. Y.	162 608	.....	13 500 0
130.	Rockford, Ill.	31 051	22 000	2 600 0
89.	Saginaw, Mich.	42 345	28 000	7 500 0
4.	St. Louis, Mo.	575 200	400 000	63 530 0
23.	St. Paul, Minn.	163 065	125 000	8 337 0
110.	Salem, Mass.	35 956	35 700	.....
70.	Salt Lake City, Utah	53 531	55 000	12 000 0
71.	San Antonio, Tex.	53 321	.....	8 500 0
9.	San Francisco, Cal.	342 800	.....	25 000 0
69.	Savannah, Ga.	54 244	55 000	6 000 0
127.	Schenectady, N. Y.	31 682	27 000	6 000 0
123.	Sioux City, Ia.	33 111	.....	1 427 0
48.	Seattle, Wash.	80 671	60 000	8 500 0
105.	Spokane, Wash.	36 848	32 000	7 925 0
61.	Somerville, Mass.	61 643	62 000	.....
60.	Springfield, Mass.	62 059	48 200	5 471 5
101.	Springfield, Ohio	38 253	33 000	3 000 0
116.	Springfield, Ill.	34 159	18 000	4 000 0
129.	Superior, Wis	31 091	.....	2 000 0
30.	Syracuse, N. Y.	108 374	.....	11 000 0
103.	Tacoma, Wash.	37 714	40 000	4 000 0
131.	Taunton, Mass.	31 036	26 100	1 620 0
106.	Terre Haute, Ind.	36 673	.....	3 500 0
26.	Toledo, Ohio	131 822	65 384	7 750 0
121.	Topeka, Kan.	33 608	.....	1 900 0
53.	Trenton, N. J.	73 305	71 610	7 090 0
62.	Troy, N. Y.	60 651	58 000	10 600 0
66.	Utica, N. Y.	56 383	.....	3 000 0
81.	Waterbury, Conn.	45 859	.....	6 000 0
12.	Washington, D. C.	287 700	270 000	50 000 0
97.	Wheeling, W. Va.	38 878	.....	9 500 0
51.	Wilmington, Del.	76 508	76 500	6 930 0
141.	Williamsport, Pa.	28 757	26 000	4 500 0
146.	Woonsocket, R. I.	28 204	32 000	933 0
29.	Worcester, Mass.	118 421	113 000	7 920 0
79.	Yonkers, N. Y.	47 931	45 000	3 627 0
119.	York, Pa.	33 708	36 000	2 850 0

* The average per capita consumption and receipts are based on the pop census of 1900.

† D = Department; C = Consumer; B = Both.

000 000	102	.....	....	2 000	500	1.20	C	C
.....	62	420 000	2.56	13 000	5 200	40.00	C	C
301 000	84	Private.	....	2 370	750	31.65	C	C
800 000	120	Private.	....	4 250	380	8.94	B	B
585 000	193	33 150	1.14	3 300	40	1.21	C	C
000 000	145	103 000	2.48	6 000	500	8.33	B	B
204 000	56	103 600	1.81	5 926	4 386	74.01	C	C
250 000	47	Private.	....	1 500	1 482	99.47	D	C
000 000	80	40 000	1.60	3 550	2 000	56.34	C	C
000 000	189	Private.	....	22 000	600	2.72	B	B
.....	100	557 000	3.48	20 755	1 560	7.52	D	D
000 000	85	202 000	2.15	10 634	5 586	52.53	C	C
660 000	64	210 000	2.88	12 577	2 500	19.88	B	B
700 000	50	112 000	3.33	6 426	2 935	45.67	D	D
500 000	61	138 000	2.42	5 500	3 700	67.27	D	D
500 000	73	50 000	1.46	3 833	754	19.67	B	C
000 000	125	Private.	....	9 666	800	8.28	D	D
000 000	80	430 000	1.43	41 485	28 039	67.59	C	C
813 000	93	225 000	1.11	18 800	5 175	27.53	B	C
800 000	144	36 300	1.86	3 890	31	0.80	D	D
300 000	140	140 000	1.73	7 720	3 200	41.45	B	B
000 000	94	690 300	2.71	33 500	7 342	21.92	B	B
320 000	115	181 600	3.30	9 280	1 429	15.40	B	B
.....	150	56 400	2.26	3 259	180	5.52	C	C
.....	150	Private.	....	14 500	375	2.58	D	D
820 000	48	Private.	....	.....	....	....	C	C
000 000	71	55 000	1.94	5 000	470	9.40	C	C
086 000	64	131 000	3.99	7 087	6 001	84.68	C	D
000 000	116	6 200 000	1.80	.....	44 000	....	C	C
250 000	131	115 000	2.88	8 500	178	2.09	C	C
500 000	156	357 000	4.46	16 900	1 130	6.69	D	D
000 000	176	Private.	....	11 000	3 800	34.55	C	C
500 000	88	Private.	....	1 773	51	2.88	C	C
500 000	90	Private.	....	2 900	929	32.03	D	D
300 000	129	Private.	....	11 108	2 299	20.71	D	D
524 000	82	193 000	2.41	8 293	6 369	76.80	B	B
500 000	62	Private.	....	6 058	418	6.90	D	D
188 000	229	3 047 900	2.43	250 000	1 275	0.51	D	D
000 000	231	806 000	3.44	33 084	200	0.60	C	C
000 000	200	286 000	3.18	12 447	509	4.09	D	D
130 000	54	577 587	3.08	21 566	17 813	82.60	C	C
000 000	267	62 500	4.17	3 400	30	0.88	D	D
350 000	46	Private.	....	2 700	1 300	48.15	D	C
360 000	47	Private.	....	4 916	1 200	24.41	B	C
180 000	92	161 100	2.07	15 885	636	4.00	B	C
048 000	100	140 000	1.65	14 781	4 500	30.44	B	D
500 000	83	400 000	....	34 549	8 752	25.33	C	C
300 000	118	38 900	1.77	3 373	270	8.00	D	D
500 000	268	45 000	1.61	3 500	300	8.57	D	D
530 000	159	1 483 000	3.71	65 688	4 133	6.29	B	B
337 000	67	346 000	2.77	17 093	4 812	28.15	B	C
.....	70	80 000	2.24	6 400	180	2.81	D	D
000 000	218	100 000	1.82	12 000	145	1.21	D	D
500 000	159	Private.	....	9 100	100	1.10	B	B
000 000	73	Private.	....	43 000	9 900	23.02	D	D
000 000	109	80 000	1.45	8 000	45	0.56	C	C
000 000	222	75 000	2.78	7 000	20	0.29	D	D
427 000	43	43 600	1.32	3 000	1 525	50.83	B	C
500 000	142	200 473	3.34	6 181	800	12.94	D	D
925 000	248	157 500	4.92	5 000	165	3.30	D	C
.....	88	210 000	3.39	10 000	200	2.00	D	D
471 500	113	243 700	5.06	9 764	3 122	31.97	C	C
000 000	91	43 000	1.30	4 200	200	4.76	B	D
000 000	222	67 000	3.72	3 000	230	7.67	C	C
000 000	64	Private.	....	1 800	140	7.77	C	C
000 000	102	273 000	2.52	17 000	8 037	47.28	C	C
000 000	100	95 000	2.37	4 500	500	11.11	D	D
320 000	62	60 600	2.32	4 502	1 832	40.69	C	D
500 000	95	Private.	....	4 265	285	6.68	D	D
750 000	119	140 000	2.14	11 888	5 975	50.26	C	C
000 000	56	Private.	....	2 900	550	18.97	B	B
990 000	99	116 700	1.63	.....	190	....	D	D
800 000	183	104 500	1.80	7 500	314	4.19	D	C
000 000	53	Private.	....	7 064	6 838	96.80	C	C
000 000	131	115 500	2.51	4 899	486	9.92	D	D
000 000	185	350 000	1.30	45 000	1 200	2.67	C	C
400 000	244	100 000	2.52	.....	6	....	D	D
830 000	90	162 300	2.12	15 000	640	4.27	D	D
00 000	173	Private.	....	4 371	85	1.94	D	D
933 000	29	72 800	2.28	2 347	2 136	91.01	D	D
920 000	70	262 175	2.32	13 292	12 536	94.31	C	C
227 000	81	147 944	3.29	4 968	4 852	97.67	C	C
150 000	79	93 000	2.58	8 300	275	3.31	D	D

he population supplied, where reported; otherwise, on the population by

we did not understand exactly what was meant in the several cases, we adopted the method stated above.

In regard to cost, we find $2.25 to be the annual per capita cost for water in all cities, indicating no difference in dollars alone to the water consumer for whatever method of charge is adopted. This is surprising, especially as it follows out in each of the metered percentage groups, and it would almost appear to be simply a coincidence. It may be explained that as the general use of water meters is comparatively recent in American cities, and as the works were installed and the water debt incurred before the use of meters, a sufficient time has not elapsed for them to have had their full effect on the water rates. If it is a coincidence, it shows conclusively that meter charges do not, as claimed, increase the cost to consumers.

A summary and averages of the detailed figures given in Table I are presented in Table II, classified in accordance with the percentage of taps metered.

TABLE II. — POPULATION, WATER CONSUMPTION, AND RECEIPTS FOR WATER, SUMMARIZED AND AVERAGED IN ACCORDANCE WITH PERCENTAGE OF TAPS METERED.*

Percentage of Taps Metered.	Number of Cities.	Population.*	Consumption (Gallons per Day).		Number of Cities.	Population.*	Receipts.	
			Total.	Average per Consumer.			Total.	Average per Consumer.
0 to 10	71	12 713 866	1 947 378 000	153	53	11 802 154	$26 432 316	$2.24
10 to 25	18	1 657 454	182 991 000	110	12	1 108 142	2 491 719	2.25
25 to 50	22	1 686 635	175 632 000	104	17	1 448 633	3 255 149	2.25
50 to 100	23	1 600 333	109 616 000	62	20	1 455 442	3 253 606	2.24
Totals and Averages	134	17 658 288	2 415 617 000	137	102	15 814 371	$35 432 790	$2.24

The results obtained are general, apply to no especial city or location, and their only purpose is to afford figures for ready comparison, and to identify the thing we have all heard of and never have seen, namely, the per capita consumption of water in American cities.

There is one result that stands forth preëminently, namely, that

* The table is based on the population supplied, where separately reported; otherwise on the total population by the census of 1900.

the average per capita consumption is twice as great as it should reasonably be, and that cities which are now in distress from danger of a water famine, and are consequently in search of additional supplies, can, by applying proper methods of conservation to their present supplies, more quickly and cheaply relieve themselves from their distresses, and by so doing have an abundant and adequate supply of water for twice as many inhabitants as they now have.

EDITORIAL DISCUSSION IN "ENGINEERING NEWS."

Selling water by guess has now few advocates among water-works engineers and superintendents. In fact, nearly all men held directly responsible for ample and pure municipal water supplies have had the necessity of using meters forced home in such a variety of ways that they now believe in as rapid an extension of the meter system as popular feeling, or prejudice, will permit. The extent to which these convictions, on the one hand, and prejudices on the other, prevail in the larger cities of the United States is indicated by the foregoing figures on water consumption and the use of meters during the year 1900. The responses made to Mr. Bailey's inquiries, both in numbers and completeness, reflect in no small degree the interest which the subject now excites in the minds of water-works officials. The replies are also a gratifying example of the spirit of coöperation which exists among the more intelligent and specially trained class of municipal officials.

The important results of Mr. Bailey's work are condensed in a half-dozen lines, showing that the average daily per capita water consumption of 134 cities was 137 gallons; that those having less than 10 per cent. of their taps metered consumed 153 gallons; while the average per capita consumption where over 50 per cent. of the taps were metered was only 62 gallons, or 45 per cent. of the average for the whole 134 cities.

Some comparison between conditions existing in 1900 and in 1890 may be interesting and profitable. *Engineering News* of January 16, 1892, contained statistics showing the consumption of water and use of meters in the fifty largest cities of the United States, and in all other communities having 50 per cent. or more of their taps metered.* In Table III, herewith, we have compared these earlier figures with

* Based on figures given in "The Manual of American Water Works for 1891." The article in question will be found also in the introduction to the "Manual" for the year named.

TABLE III. — PERCENTAGE OF TAPS METERED AND PER CAPITA WATER CONSUMPTION IN THE FIFTY LARGEST CITIES OF THE UNITED STATES IN 1890 AND IN 1900, ARRANGED IN ORDER OF POPULATION.*

	Cities.	Percentage of Taps Metered.		Per Capita Consumption (Gallons).		Increase or Decrease of Consumption in 10 Years (Gallons).
		1890	1900	1890	1900	
1.	New York †	20.2	..	79	116	+ 37
2.	Chicago	..	3.3	140	190	+ 50
3.	Philadelphia	0.3	0.5	132	229	+ 97
4.	Brooklyn †	2.5	..	72	...	..
5.	St. Louis	8.2	6.3	72	159	+ 87
6.	Boston	5.0	5.5	80	143	+ 63
7.	Baltimore	0.1	1.5	94	97	+ 3
8.	San Francisco	41.4	23.0	61	73	+ 12
9.	Cincinnati	4.1	7.6	112	121	+ 7
10.	Cleveland	5.8	4.9	103	159	+ 56
11.	Buffalo	0.2	1.6	186	233	+ 47
12.	New Orleans	0.4	..	37‡	48‡	+ 11
13.	Pittsburg	0.2	0.6	144	231	+ 87
14.	Washington	0.3	2.7	158	185	+ 27
15.	Detroit	2.1	10.0	161	146	— 15
16.	Milwaukee	31.9	67.6	110	80	— 30
17.	Newark	2.4	21.9	76	94	+ 18
18.	Minneapolis	6.3	27.5	75	93	+ 18
19.	Jersey City	1.2	2.0	97	160	+ 63
20.	Louisville	5.9	7.5	74	100	+ 26
21.	Omaha	19.4	34.6	94	176	+ 82
22.	Rochester	11.4	25.3	66	83	+ 17
23.	St. Paul	4.2	28.2	60	67	+ 7
24.	Kansas City	17.6	40.0	71	62	— 9
25.	Providence	62.4	82.6	48	54	+ 6
26.	Denver	0.8	1.2	..	300	..
27.	Indianapolis	7.6	6.0	71	79	+ 8
28.	Allegheny	0.0	..	238	..	..
29.	Albany	0.4	12.3	..	191	..
30.	Columbus	6.4	34.0	78	230	+152
31.	Syracuse	14.6	47.3	68	102	+ 34
32.	Worcester	89.4	94.3	59	70	+ 11
33.	Toledo	9.4	50.3	72	119	+ 37
34.	Richmond	1.4	30.4	167	100	— 67
35.	New Haven	..	2.6	135	150	+ 15
36.	Paterson	..	20.7	128	129	+ 1
37.	Lowell	22.9	52.5	66	85	+ 19
38.	Nashville	0.8	41.5	146	140	— 6
39.	Scranton	..	...	..	..	..
40.	Fall River	74.6	94.3	29	36	+ 7
41.	Cambridge	2.4	6.1	64	79	+ 15
42.	Atlanta	89.6	91.6	36	84	+ 48
43.	Memphis	3.7	8.3	124	125	+ 1
44.	Wilmington	0.2	4.3	113	90	— 23
45.	Dayton	3.8	46.7	47	62	+ 15
46.	Troy	3.9	4.2	125	183	+ 58
47.	Grand Rapids	..	13.4	..	156	..
48.	Reading	0.1	4.0	75	92	+ 17
49.	Camden	..	1.4	131	280	+149
50.	Trenton	..	..	62	99	+ 37

* The classification is by the census of 1890, so as to include all the cities in the earlier grouping.
† New York and Brooklyn consolidated since 1890.
‡ Only a small part of the population supplied.

those given in Mr. Bailey's article, stopping, however, with the fifty largest cities in the 1890 list. The final column of the table gives the increase or decrease in per capita consumption during the ten years from 1890 to 1900.

Perhaps it should be pointed out that the figures for consumption ought not to be compared in too great detail, since all the 1890 averages of consumption were based on the total populations of the respective cities, while Mr. Bailey used, for his computations, the actual populations supplied, when reported; otherwise, the 1900 census figures. Mr. Bailey was justified in this, since he contents himself with giving the actual figures reported and a few broad generalizations, based on averages. Notwithstanding the possible discrepancies named, it seemed desirable to place the two sets of figures side by side, for comparison, with the suggestion that the warning here given be kept in mind. A reference to Mr. Bailey's Table I will show whether his per capita consumption is based on the 1900 census or the estimated population supplied. Perhaps the most notable instance of the difference in results obtained by the two methods is shown by St. Louis. According to Table III, its per capita consumption increased from 72 to 159 gallons, in the ten years, from 1890 to 1900. But Mr. Bailey's report from St. Louis placed the population supplied at 400 000, while the 1900 census showed a total population of 575 200. Using the latter figure as a divisor, the per capita consumption in St. Louis for 1900 was 110 gallons, or an increase of 53 per cent. over 1890, instead of 120 per cent. Even the 53 per cent. is bad enough. It is to be accounted for, at least in part, by a diminution of the percentage of taps metered, which was 8.2 in 1890, and 6.3 in 1900. The same sort of calculation helps to explain why a marked increase in the use of meters at Columbus, Ohio, from 6.4 to 34.0 per cent., should be accompanied with an increase in consumption from 78 to 230 gallons, or nearly 200 per cent. The report sent to Mr. Bailey from Columbus gave the population supplied as 100 000; the total population in 1900 was 125 560. On the latter basis, the per capita consumption becomes 183 gallons. In addition to this, the 1900 returns show that there was one tap in use for every 8.6 consumers, whereas the consumers per tap in 1890 averaged 11.5. In other words, using the total population in 1890 to find the per capita consumption was more misleading than in 1900, since relatively fewer people were supplied with water then. Thus the wisdom of using the actual population supplied, when you can

get it, is emphasized. On the other hand, it is evident that the round 100 000 population in Mr. Bailey's table is merely a local guess, and by adopting such guesses for some cities and using total populations for others, where guesses are perhaps more needed, it is questionable whether the comparative value of the figures is made greater than when total population is used. This is particularly true in a census year. At other times, all the populations are guesses. If an estimate of the population actually supplied is needed anywhere it is in the case of New Orleans. No such estimate was reported, so Mr. Bailey used the total population, thus showing an apparent consumption of 48 gallons per capita in a city having but 0.4 per cent. of its taps metered. In justice to Mr. Bailey, we again call attention to the fact that his main idea was to secure broad general averages, which may be but little affected by the above considerations. Probably there is not another large city in the United States where so small a proportion of the population uses the public water supply. When the city regains control of the works, and installs a purification plant in accordance with the teachings of the investigations it now has under way, probably the people will go back from their cisterns to the public water supply which so many of them abandoned years ago on account of its muddiness.

Leaving these details and possible discrepancies, one may find plenty of instruction from the broad general teachings of the comparative figures. As a rule, the cities that show the greatest increase in consumption also show but little increase in relative number of meters used, while many of the notable and some of the small increases in meter percentages are accompanied by notable decreases in consumption. The five cities with decreased consumptions have each made decided gains in the percentages of taps metered.

To make it still more evident that, as a rule, cities with high consumption employ but few meters, the figures for both 1890 and 1900, given in Table III, have been rearranged in Table IV, in order of consumption per capita, greatest to least. It will be noticed that in 1890 all the cities, with one exception, using over 100 gallons a day, had less than six per cent. of their taps metered. This exception was Milwaukee, which had 31.9 per cent. of its taps metered in 1890 and stood No. 17 in the list. In 1900 Milwaukee had 67.6 per cent. of its taps metered; its consumption had fallen to 80 gallons, and its rank to No. 37. It is very significant that the list for 1900 shows 28 cities with a consumption of 100 gallons and more per capita,

TABLE IV.—WATER CONSUMPTION AND PERCENTAGE OF TAPS METERED IN THE LARGEST CITIES OF THE UNITED STATES, ARRANGED IN ORDER OF CONSUMPTION.*

IN 1890.				IN 1900.			
Rank.	City.	Consumption (Gallons).	Percentage of Taps Metered.	Rank.	City.	Consumption (Gallons).	Percentage of Taps Metered.
1.	Allegheny	238	0.0	1.	Denver †	300	1.2
2.	Buffalo	186	0.2	2.	Allegheny	?	?
3.	Richmond	167	1.4	3.	Camden	280	1.4
4.	Detroit	161	2.1	4.	Buffalo	233	1.6
5.	Washington	158	0.3	5.	Pittsburg	231	0.6
6.	Nashville	146	0.8	6.	Columbus	230	34.0
7.	Pittsburg	144	0.2	7.	Philadelphia	229	0.5
8.	Chicago	140	....	8.	Albany	191	12.3
9.	New Haven	135	....	9.	Chicago	190	3.3
10.	Philadelphia	132	0.3	10.	Washington	185	2.7
11.	Camden	131	Small	11.	Troy	183	4.2
12.	Paterson	128	Small	12.	Omaha	176	34.6
13.	Troy	125	3.9	13.	Jersey City	160	2.0
14.	Memphis	124	3.7	14.	St. Louis	159	6.3
15.	Wilmington	113	0.2	14.	Cleveland	159	4.9
16.	Cincinnati	112	4.1	15.	Grand Rapids	156	13.4
17.	Milwaukee	110	31.9	16.	New Haven	150	2.6
18.	Cleveland	103	5.8	17.	Detroit	146	10.0
19.	Jersey City	97	1.2	18.	Boston	143	5.5
20.	Baltimore	94	0.1	19.	Nashville	140	41.5
20.	Omaha	94	19.4	20.	Paterson	129	20.7
21.	Boston	80	5.0	21.	Memphis	125	8.3
22.	New York	79	20.2	22.	Cincinnati	121	7.6
23.	Columbus	78	6.4	23.	Toledo	119	50.3
24.	Newark	76	2.4	24.	New York	116	....
25.	Reading	75	0.1	25.	Syracuse	102	47.3
25.	Minneapolis	75	6.3	26.	Richmond	100	30.4
26.	Louisville	74	5.9	26.	Louisville	100	7.5
27.	Toledo	72	9.4	27.	Trenton	99	....
27.	Brooklyn	72	2.5	28.	Baltimore	97	1.5
27.	St. Louis	72	8.2	29.	Newark	94	21.9
28.	Indianapolis	71	7.6	30.	Minneapolis	93	27.5
28.	Kansas City	71	17.6	31.	Reading	92	4.0
29.	Syracuse	68	14.6	32.	Wilmington	90	4.3
30.	Lowell	66	22.9	33.	Lowell	85	52.5
30.	Rochester	66	11.4	34.	Atlanta	84	91.6
31.	Cambridge	64	2.4	35.	Rochester	83	25.3
32.	Trenton	62	Small	36.	Milwaukee	80	67.6
33.	San Francisco	61	41.4	37.	Cambridge	79	6.1
34.	St. Paul	60	4.2	37.	Indianapolis	79	6.0
35.	Worcester	59	89.4	38.	San Francisco	73	23.0
36.	Providence	48	62.4	39.	Worcester	70	94.3
37.	Dayton	47	3.8	40.	St. Paul	67	28.2
38.	New Orleans	37	0.4	41.	Kansas City	62	40.0
39.	Atlanta	36	89.6	42.	Dayton	62	46.7
40.	Fall River	29	74.6	43.	Providence	54	82.6
				44.	New Orleans	48	....
				45.	Fall River	36	94.3

* A few cities are omitted from each list, on account of missing figures. This table is based on Table I, which in turn was based on the classification of the census of 1890, instead of that of 1900.

† In Denver, water is used for irrigation.

against 18 in 1890, notwithstanding the marked increase in the use of meters in some of these cities. What the increase in the number of cities using more than 100 gallons a day would have been without the added percentage of meters, and what it might have been had meters been used more freely, one can only conjecture. Looked at another way, it may be seen, in the 1900 list, that of 18 cities having a consumption below 100 gallons per capita, 13 have over 20 per cent. of their taps metered.

It is gratifying to note that in more than half the cities shown in Mr. Bailey's Table I, the meters are furnished by the water department, and that in quite a number of additional cities the department supplies a part of them. As the practice of furnishing, setting, and repairing water meters by the department, rather than the consumer, increases, the public prejudice against meters will also decrease. The charging of meters, in liberal numbers, to capital account will diminish the capital account for reservoirs, pumps, and mains, and this saving will in most cases far more than offset the investment in meters.

PROCEEDINGS.

March Meeting.

Young's Hotel,
Boston, March 13, 1901.

President Crandall in the chair.

The following members and guests were in attendance: —

Members.

Charles H. Baldwin, Lewis M. Bancroft, Frank A. Barbour, Joseph E. Beals, James F. Bigelow, Dexter Brackett, Edwin C. Brooks, Fred Brooks, Walter I. Brown, James Burnie, George Cassell, George F. Chace, G. L. Chapin, John C. Chase, William F. Codd, Freeman C. Coffin, R. C. P. Coggeshall, Byron I. Cook, F. H. Crandall, Arthur W. Dean, A. O. Doane, Eben R. Dyer, Charles H. Eglee, Frank L. Fuller, Julius C. Gilbert, D. H. Gilderson, J. F. Gleason, Albert S. Glover, Amos A. Gould, Richard A. Hale, Frank E. Hall, John O. Hall, J. C. Hammond, Jr., George W. Harrington, T. G. Hazard, Jr., Horace G. Holden, John L. Howard, Willard Kent, Horace Kingman, Charles F. Knowlton, James W. Locke, A. E. Martin, William E. Maybury, Frank E. Merrill, Leonard Metcalf, Thomas Naylor, Frank L. Northrop, John H. Perkins, Dwight Porter, J. B. Putnam, A. H. Salisbury, Walter H. Sears, William T. Sedgwick, Edward M. Shedd, Charles W. Sherman, George H. Snell, George A. Stacy, Frederic P. Stearns, Charles N. Taylor, Lucian A. Taylor, Harry L. Thomas, Robert J. Thomas, William H. Thomas, D. N. Tower, George W. Travis, W. H. Vaughn, William W. Wade, Charles K. Walker, George E. Wilde, Frank B. Wilkins, George E. Winslow.

Associates.

Builders Iron Foundry, by Frederick N. Connet; Chapman Valve Co., by Edward F. Hughes; Charles A. Claflin & Co., by Charles A. Claflin; Coffin Valve Co., by H. L. Weston; George E. Gilchrist, by E. C. Jacobs; Hersey Mfg. Co., by Albert S. Glover; Henry F. Jenks; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Libbey, Parker & Co., by Henry N. Libbey; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey and J. L. Wertz; Perrin, Seamans & Co., by James C. Campbell; Sweet & Doyle, by Richard Hewins; Union Water Meter Co., by J. K. P. Otis,

Albert S. Otis, and Frank L. Northrop; United States Cast Iron Pipe & Foundry Co., by John M. Holmes.

GUESTS.

Macy S. Pope, Boston, Mass.; Henry Brown, Nantucket, Mass.; L. H. Pease, Member Water Board, New Bedford, Mass.; C. A. French, Superintendent of Streets, Marlboro, Mass.; H. A. Monk, Town Clerk, Braintree, Mass.; James I. Lairel, Plymouth, Mass.; Hamilton Flood, City Engineer, Quincy, Mass.; Fred Crosby, Montgomery, Ala.; Thomas Bell, St. John, N. B.; Dr. George W. Field, Massachusetts Institute of Technology, Boston, Mass.; I. T. Inman, Attleboro, Mass.; E. L. Dunning, Boston, Mass.; Fred J. Rourke, Purchasing Agent, and Michael J. Dowd, Water Commissioner, Lowell, Mass.; Walter E. Lord, Chairman Water Commissioners, Ipswich, Mass.; George Goodhue, Concord, Mass.; A. Plouff, Boston, Mass.

The Secretary read the names of the following applicants for membership, who were recommended for election by the Executive Committee: —

For Resident Member.

Dr. George W. Field, teacher of biology, Massachusetts Institute of Technology.

Hiram Allen Miller, Department Engineer, Metropolitan Water Works, Clinton, Mass.

Macy Stanton Pope, Inspector, Factory Mutual Insurance Co.'s, 31 Milk Street, Boston.

C. P. Moat, Chemist, Vermont State Board of Health, Burlington, Vt.

Dr. B. N. Stone, Biologist, Vermont State Board of Health, Burlington, Vt.

George D. Nash, Superintendent Winooski Aqueduct Co., Winooski, Vt.

John W. Moran, Superintendent Water Works, Gloucester, Mass.

On motion of Mr. Coggeshall, the Secretary was directed to cast the ballot of the Association in favor of the applicants, which he did, and they were declared elected.

The President called attention to hearings before the Committee on Water Supply of the Massachusetts Legislature on the 20th inst., upon bills regulating charges by private water companies or corporations, and to constitute the Board of Gas and Electric Light Commissioners the Board of Gas, Electric Light, and Water Commissioners, having supervision of private water companies.

THE JOURNAL.

MR. C. W. SHERMAN.* I would like to say just a word, Mr. President, with reference to the annual reports. It is about the time when most of the superintendents are getting out their reports, and, as you all know, it is a part of the business of the Association to get together as far as possible the statistics given in these reports for publication in the JOURNAL. I want to call the attention of the superintendents here present to this matter, and ask them to be sure to see to it that copies of their reports are sent to the Association headquarters.

We have prepared a blank form for the Summary of Statistics, so that it is only necessary to put in the figures in the proper places, and cross out the items not applicable to your particular works. These have been printed in such a manner that the leaves can be separated and used as part of the copy for the annual report; and I should be very glad to send copies to any one who will use them.

MR. R. J. THOMAS.† I would like to call the attention of the members present to the importance of consulting the advertising pages of the JOURNAL when they are about to purchase supplies for their departments. It is probable that some of you do not realize the fact that a large proportion of our members depend upon the JOURNAL for all the benefit that they get from this Association; the quarterly publication which they receive is the only return they get for their money. That is, of course, on account of the fact that they live so far from Boston it is inconvenient for them to attend our meetings.

Now, the success of the JOURNAL depends to a large extent upon the revenues received from advertising; and the men dealing in supplies will not advertise in the JOURNAL unless they find it is profitable for them to do so, and it rests with the members of this Association to make it pay these men to advertise. We have now about six hundred members, and if they will give the advertising patrons of the JOURNAL a preference, or if they will at least consult them and obtain their figures on supplies when about to purchase, it would certainly be an object for every man in the water-works supplies line to have an advertisement in our JOURNAL. There are many who do not advertise with us now, but who I have no doubt would

* Editor, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.
† Advertising Agent, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

be glad to avail themselves of the pages of the JOURNAL for reaching the members, providing the members would only bear them in mind and consult the advertising pages when they wanted anything in any special line. We want to get as many of the water-works supplies men to advertise in the JOURNAL as possible, and the assistance of all the members is requested to that end.

THE PRESIDENT. I think we can all appreciate the importance and value of what our advertising agent has just said, and we are no doubt all glad to do what we can in seconding his efforts to make the JOURNAL a financial success.

The President then opened the discussion upon the subject, "When Necessary to Assess the Annual Cost of Fire Protection upon the Parties Directly Benefited, how can the Assessment be most Equably Apportioned?"* The subject was further discussed by Messrs. Charles K. Walker, Macy S. Pope, J. Waldo Smith, F. N. Connet, J. C. Hammond, Jr., John C. Chase, Horace G. Holden, and Prof. William T. Sedgwick.

On motion of Mr. Byron I. Cook, a committee of five was appointed by the President to consider the subject further and to report at a future meeting. The President appointed as the committee: Messrs. Byron I. Cook, Edward V. French, J. C. Hammond, Jr., Charles K. Walker, and John C. Chase.

Dr. George W. Field, of the Massachusetts Institute of Technology, Boston, then gave an interesting talk on "Eels in Water Works and their Control." Questions were asked and experiences told by Messrs. D. H. Gilderson, George F. Chace, John C. Chase, J. C. Hammond, Jr., Harry L. Thomas, Charles W. Sherman, Leonard Metcalf, Richard A. Hale, Prof. William T. Sedgwick, George W. Travis, and others.

Adjourned.

*This is a continuation of the discussion began at the February meeting, under the title of "Charges for Private Fire Service."

OBITUARY NOTES.

Dr. Jo H. Linsley, who joined this Association March 8, 1899, died at Burlington, Vt., February 17, 1901.

Dr. Linsley was born in Windsor, May 29, 1859. He attended the public schools of Burlington, and graduated from the Medical Department of the University of Vermont in 1880. During his practice in Burlington the doctor filled the office of city physician and health officer for a number of years. In the course of his short but useful career Dr. Linsley served as instructor in clinical microscopy in the New York Post-Graduate Medical School and Hospital; director of the laboratories of histology, pathology, and bacteriology; pathologist to the New York Post-Graduate Hospital and the New York Infant Asylum; English secretary of the section for hygiene of the Tenth International Congress, held in Berlin, 1890; representative in Germany for the New York Post-Graduate School (during this period he took a course in bacteriology under Koch, and gave the first address on the lymph treatment for tuberculosis before the New York County Medical Society); professor of pathology and bacteriology at the University of Vermont; chairman on admission and ethics of the New York Pathological Society. He also was a writer and translator of several medical works.

The work for which he will be most remembered in Burlington, aside from the attractive qualities of his private life, was the establishing of the Vermont Laboratory of Hygiene, which opened in 1897 under his direction, with fittings from his private laboratory. It has grown to large proportions, and is now a regularly equipped State institution for the examination of infected water and food supplies and infectious diseases.

Dr. Linsley was an enthusiast in whatever he undertook, and will be sadly missed by a large circle of acquaintances and friends.

Patrick F. Crilly, superintendent of the Woburn, Mass., Water Works, died on Monday, March 25, 1901, at the Massachusetts General Hospital, after an unsuccessful operation.

Mr. Crilly was born in Louth, Ireland, about forty-six years ago.

He came to this country at the age of seventeen, and entered the employment of the late George H. Norman on water-works construction. In 1886 he became superintendent of the Woburn Water Works, and held this position until his death. He left a widow and two children.

Mr. Crilly became a member of this Association on March 12, 1890.

HENRY W. ROGERS, one of the founders of this Association, and its president in 1886–87, died on April 15, 1901, at the home of his sister in Haverhill, at the age of sixty-five.

He was born in Warren, Vt., and came to Boston at the age of twenty-one to begin as a pipe-layer on the Boston Gas Works. A few years later he began contracting for himself, and in 1869 went to Beverly, and was for two years occupied in that town and in Salem building water works. He was superintendent of the Salem works for a year, and then went to Lawrence, where he built the greater part of the water works, and where he remained as superintendent for eleven years. The two following years were spent in Maine, building water works at Dover, Waterville, and Calais, after which he returned to Salem, and later went to Milford. In 1892 he became superintendent of the Haverhill Water Works, and held this office for six years. He then went to Roxbury, where he was engaged in the coal business for a short time, but was soon forced to give up business by failing health. He then returned to Haverhill, and spent the remainder of his life there.

A year ago Mr. Rogers was much affected by the death of his wife, and from that time failed steadily until the end. He leaves one son.

Mr. Rogers was always very popular with those who knew him. He was quiet and unobtrusive, but of sterling worth. In his death the Association loses a valuable member.

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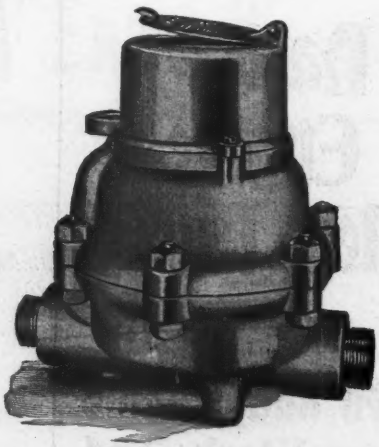

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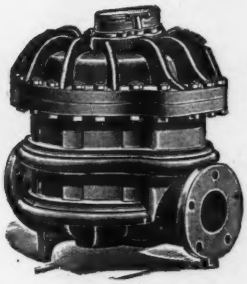

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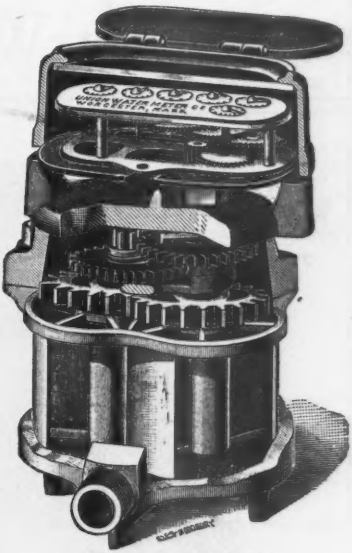

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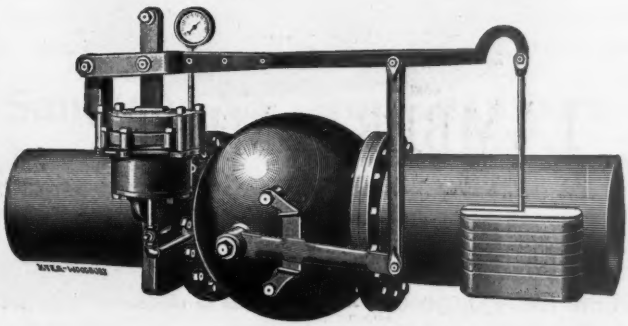

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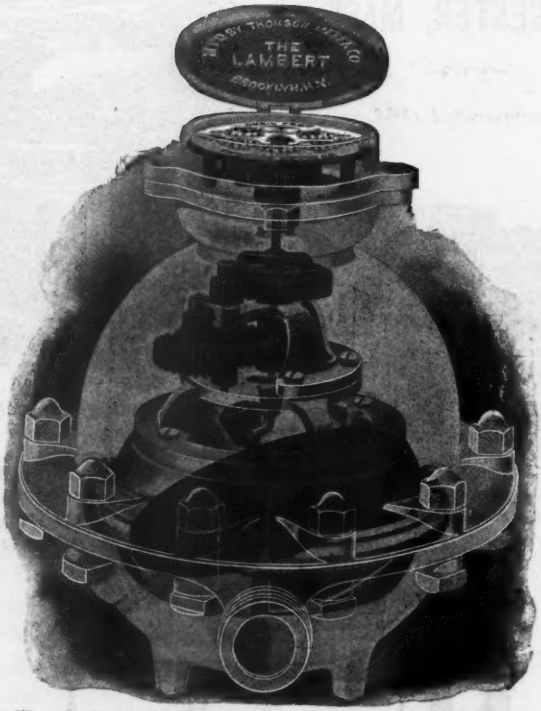

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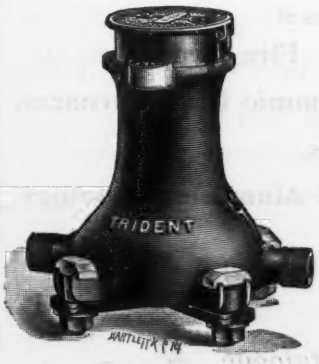

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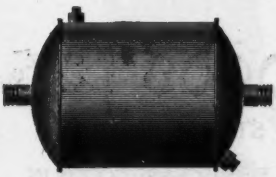

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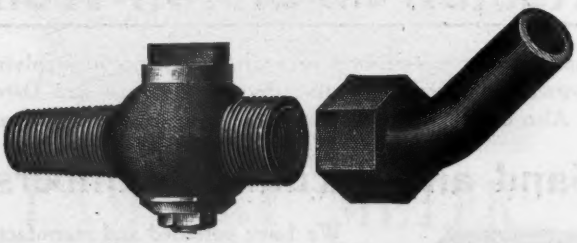

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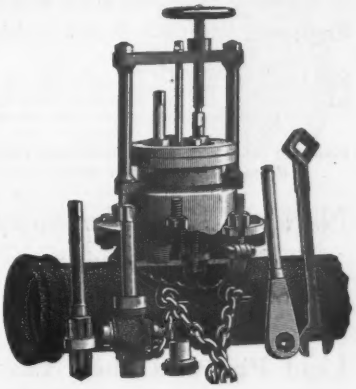

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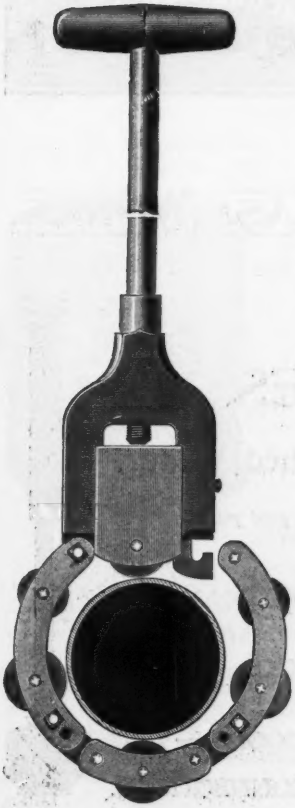

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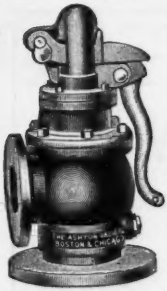

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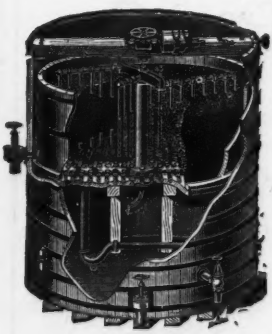

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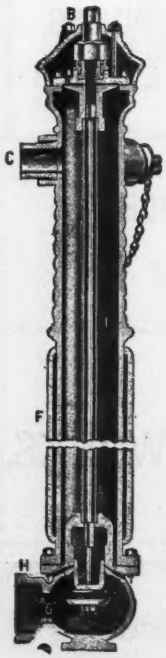

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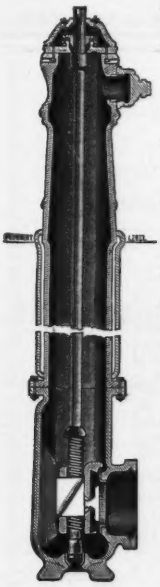

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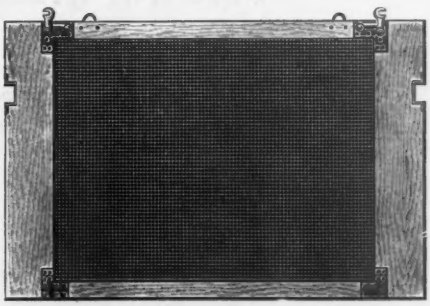

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National Foundry and Pipe Works, Scottdale, Pa. (Limited.)
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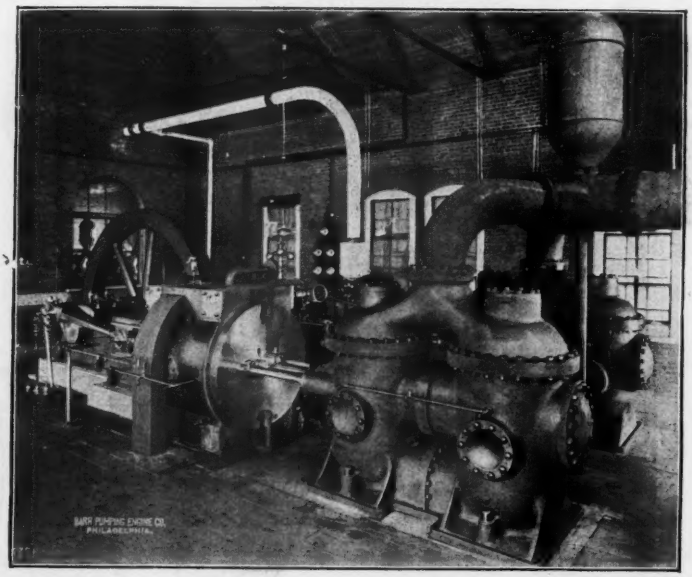

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PUMPS OF ALL DESCRIPTIONS.

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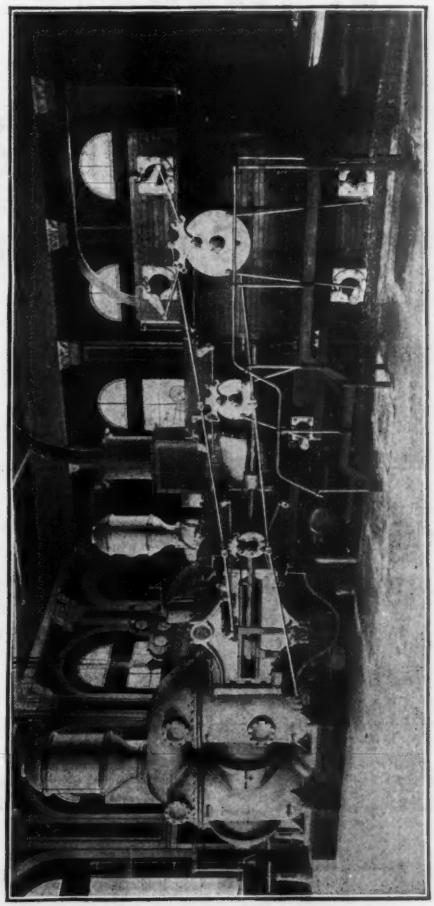

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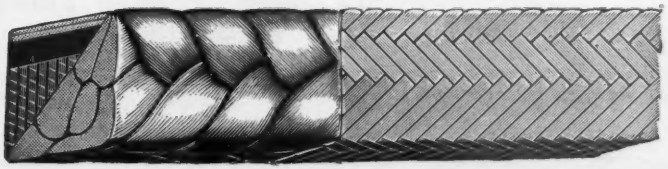

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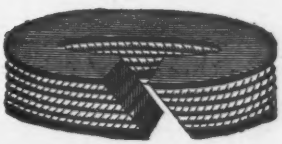

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